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Underground Mine Communications

(In Four Parts)

3. Haulage Systems

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Bureau of Mines

Information Circular 8744

Underground Mine Communications

(In Four Parts)

3. Haulage Systems

Compiled by Staff–Mining Research

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

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UNDERGROUND MINE COMMUNICATIONS

(In Four Parts)

3. Haulage Systems

Compiled by Staff–Mining Research

ABSTRACT

This volume contains a series of papers describing research conducted by the Bureau of Mines to develop or improve equipment and systems that satisfy the communication requirements of miners doing work related to rail, belt-conveyor, trackless, and hoist haulage systems.

INTRODUCTION

Operators of underground vehicles must be able to communicate with one another and with a fixed location to improve safety, efficiency, and production.

The trolley-wire phone system is the basic rail-haulage communication system. The research reported in the first paper has been devoted to improving this system. The major causes of poor performance have been identified, and techniques have been developed to improve the performance and extend the useful range of carrier-phone systems.

Recently the use of track-nontrolley and nontrack-nontrolley vehicles has increased. To maintain traffic safety and to coordinate production, the operators of these vehicles often need to communicate with other vehicle operators and other miners located at a fixed-station phone. The leaky feeder ultrahigh-frequency (UHF) radio system described in the second paper is a custom-made system installed and operating in a metal-nonmetal mine; however, the techniques can readily be applied to coal mines.

From time to time, it is necessary to move large pieces of equipment under an energized trolley wire. The communication system described in the third paper will allow the miners involved in moving the equipment to set the calibration of a breaker remotely, and to open the breaker that feeds power to the energized section of trolley wire. The system will satisfy requirements specified by the Mining Enforcement and Safety Administration (MESA) and will reduce the hazards faced when large equipment is being moved near an energized trolley wire. (Additionally, significant progress has been made on a circuit breaker that discriminates between high-current legitimate loads and

low-current faults, but this device is covered under the Bureau's seminar on power systems, rather than communications.)

The fourth paper discusses a new type of high-performance communication system for hoist systems. Originally developed to provide emergency communications for hoist-shaft and rescue capsules during mine disasters, the system has been modified for use in the normal hoisting operation. It includes on-cage bell signaling, slack-rope alarm, and shaft inspection.

In some mines, coal is loaded out from the section by bringing mainline empty cars back into the section. The movement of these cars on the section track during the loading operations requires coordination between the locomotive operator and a person called a "snapper," who couples and uncouples cars. Three methods are described in the fifth paper for providing reliable communications between the motorman and the snapper to insure the vital coordination of the actions of these two miners, thereby reducing the hazard to which the snapper is exposed.

Most of the research described is innovative because it introduces surface-communication equipment to the underground mining industry. The trackless-trolleyless medium-frequency radio described in the last paper is innovative in that new communication equipment is being developed and applied in a newly developed haulageway communication system.

Throughout this report, references to specific companies or trade names is made for information only and does not imply endorsement by the Bureau of Mines.

NEW TECHNIQUES FOR TROLLEY CARRIER-PHONE SYSTEMS

by

Harry Dobroski, Jr.,[1] and Richard H. Spencer[2]

SUMMARY

At present, two communication systems are in general use in electric-rail-haulage coal mines--pager phones and trolley carrier phones. Trolley carrier phones are essential to the safe and efficient operation of the electric-rail-haulage system. The phones operate in a wide variety of mines under difficult conditions, including the rough environment, ever-present noise, poor propagation conditions, uneven maintenance, and equipment shortcomings. The Bureau of Mines sponsored two programs to improve trolley carrier phone systems.

The first program was designed to (1) identify poor performance of trolley carrier-phone systems; (2) assess the root causes of poor performance and classify them on the basis of equipment, coupling, or transmission problems; and (3) propose and verify the means to overcome these problems by computer simulation, laboratory experiments, and in-mine testing.

The second program provided a set of guidelines for operating personnel to improve their carrier-phone system. These guidelines give detailed instructions for installing trolley carrier-phone equipment onboard mine vehicles and at the dispatcher's room, converting a rail-haulage trolley wire-rail and feeder system into a functional carrier-frequency-transmission line, checking the performance of the trolley carrier-phone system, and using portable test equipment to aid in system maintenance.

IMPROVEMENTS FOR MINE CARRIER-PHONE SYSTEMS

Dead spots, areas where two-way communication between a vehicle and a dispatcher is not possible, are caused by extreme attenuation of signals, excess noise, and/or inadequate squelch control. The most significant of these causes is the extreme attenuation of the carrier-phone signals on the trolley wire-rail. The trolley wire-rail is a poor radio-frequency transmission line for several reasons, the most dominant of which is the presence of many bridging loads across the trolley wire-rail. Branches and the lack of terminations contribute to the problem as well. The bridging loads, which both absorb and reflect power, comprise such items as personnel heaters, rectifiers, pumps, haulage vehicles (motors), locomotive and jeep lights, carrier phones, insulators, and signal and illumination lights. If it were possible to remove all the bridging loads from the trolley wire-rail, it would act as a good transmission line.

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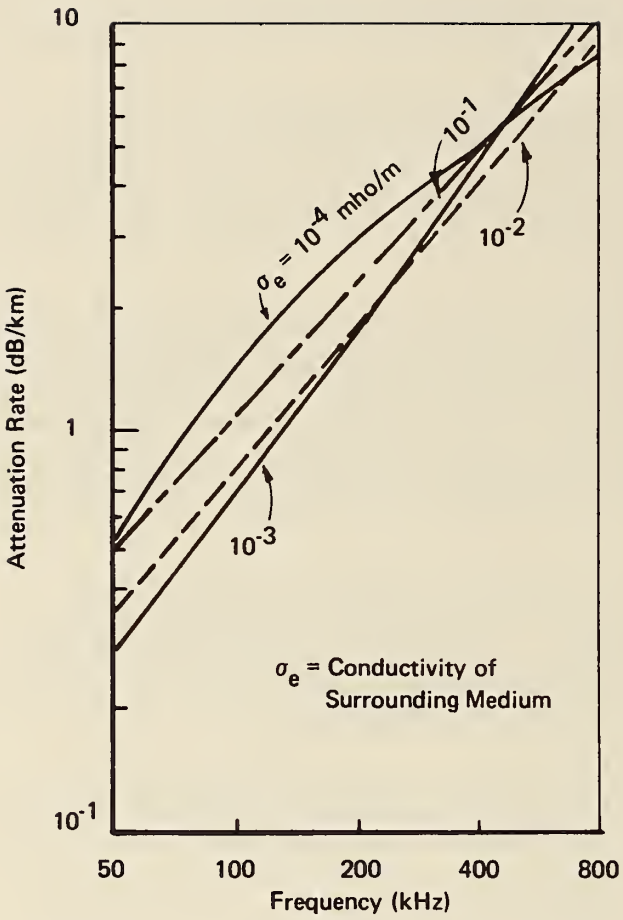

FIGURE 1. - Theoretical attenuation rate for typical trolley wire-rail.

Figure 1 illustrates the theoretical signal-attenuation rate for a trolley wire-rail transmission line. An attenuation rate of 1 decibel per kilometer is a pessimistic value to use. Thus, a trolley carrier-phone line having an allowable transmission loss of 70 decibels (from 25 volts to 8 millivolts) yields a communication range of 70 kilometers (43 miles). This performance, in the absence of bridging loads, can be compared with that of a sample trolley wire-rail loaded as illustrated in figure 2. Here, just three bridging loads of modest value (typical of vehicles and personnel heaters) reduce the signal 55 decibels over a distance of just 4,500 feet. The figure also shows the signal level that would exist over the same distance on a properly terminated trolley wire-rail without bridging loads. With such signal reductions, it is easy to see why it is difficult to obtain long-range transmission of carrier signals in a coal mine.

OVERCOMING THE EFFECT OF BRIDGING LOADS

Two approaches that appear to have merit in overcoming the exceptionally high attenuation rates that can be expected on the trolley wire-rail are the low-impedance line and the dedicated wire.

Low-Impedance Line

A bridging load on a transmission line reduces the line voltage to the fraction $\frac{R}{R + Z_o/2}$. It is apparent from the form of this expression that the loss of signal caused by a bridging load is related not only to the value of the bridging resistance, R, but also to the characteristic impedance of the transmission line Z_o. Thus, if the characteristic impedance of the line could be lowered significantly, the loss imposed by a bridging load would decrease. In this method of improving signal propagation, the characteristic impedance of the line is artificially lowered by loading the trolley wire-rail periodically with fixed values of capacitance. The way in which the characteristic impedance Z_o depends on this added capacitance can be expressed by $Z_o = \sqrt{\frac{L}{C + C_a}}$, where Z_o is the characteristic impedance, L is the inductance

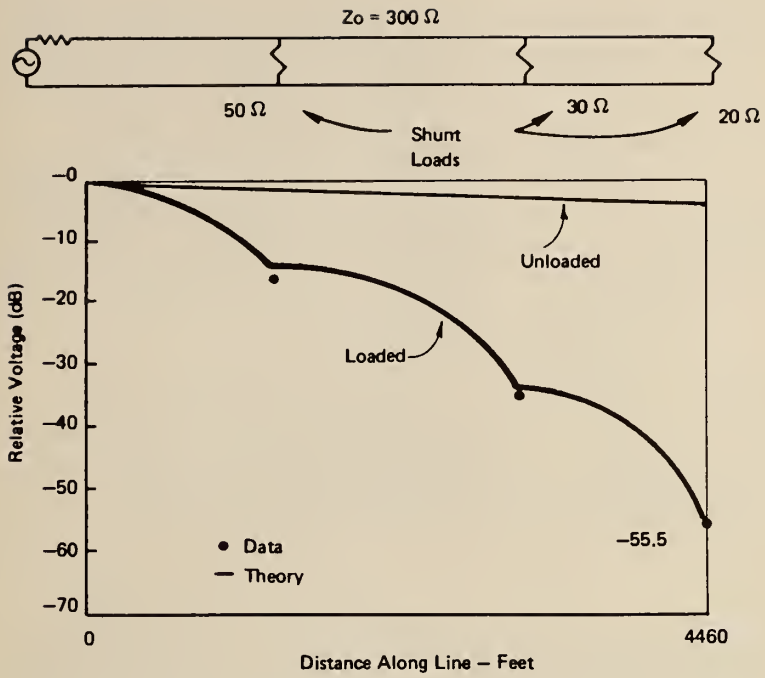

FIGURE 2. - Signal level on simulated trolley wire-rail.

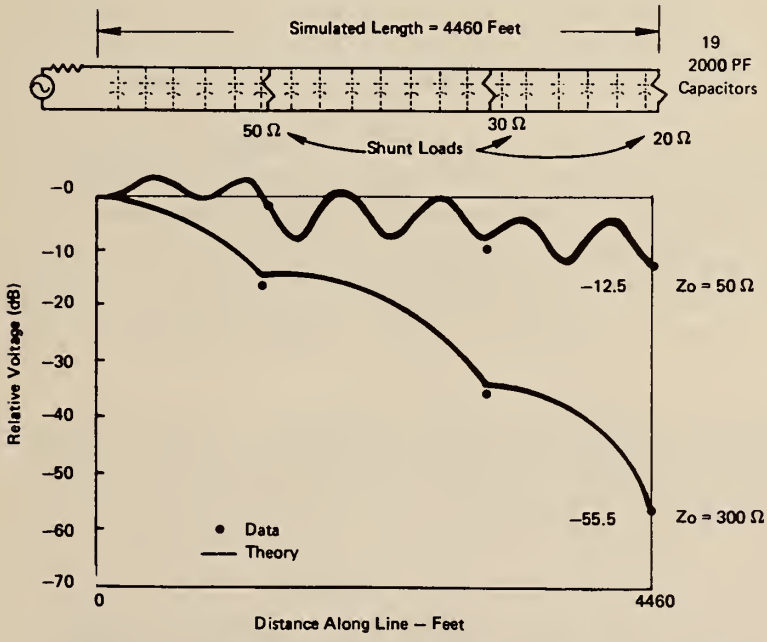

FIGURE 3. - Theory and experimental results obtained with the low-impedance technique.

per unit length, C is the capacitance per unit length, and C_a is the added capacitance per unit length.

The unloaded trolley wire-rail normally has a Z_o of about 300 ohms. If 2,000-picofarad capacitors are added at 235-foot intervals, the characteristic impedance drops to 50 ohms. The consequences of this action are shown in figure 3; namely, substantial improvement in signal level occurs when this treatment is applied to the example previously cited (trolley wire-rail with three bridging loads). A signal loss of 55 decibels is reduced to a 12-decibel loss. The plots show both the theoretical signal level and that measured for a laboratory experiment in which the trolley wire-rail was simulated. Experiments to confirm these results in an operating mine are planned.

Dedicated Wire

The second promising approach to overcoming the extremely high attenuation rates imposed by bridging loads is a single-purpose, or "dedicated," wire. The characteristics of an unloaded trolley wire-rail are such that it forms a low-loss transmission line. Therefore, a separate wire strung in an entryway, with the same rail return path as the trolley wire but unloaded by any bridging loads, would similarly serve as a low-loss line. Such a configuration forms a three-wire transmission line.

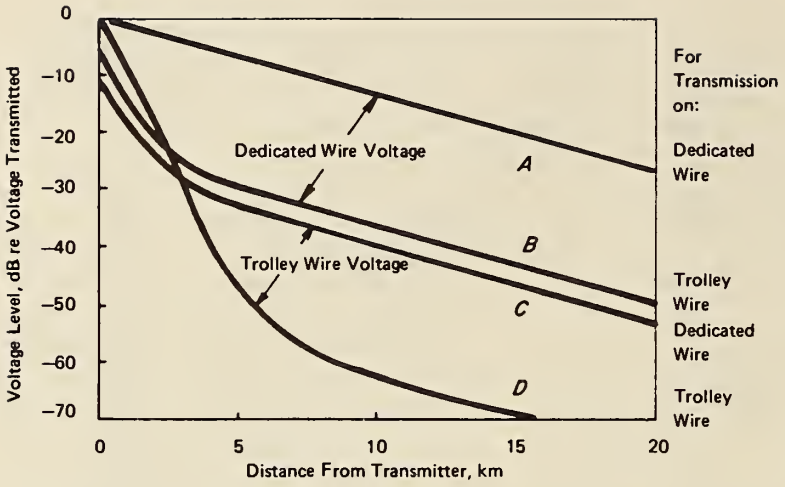

FIGURE 4. - Voltage levels versus distance for dedicated wire.

It has been shown that the dominant mode of propagation for such a configuration is a low-loss mode supported by the dedicated wire, with both the trolley wire and the rails serving as the return signal path. The signal improvements that can be expected from such a configuration are illustrated in figure 4, which shows the voltage signal strength versus the distance along a heavily loaded trolley wire-rail with a parallel dedicated wire.

Four separate conditions of transmission and reception are also shown in figure 4. For example, if the dispatcher transmits and receives on the dedicated wire, then the dispatcher's transmission will produce a curve of trolley signal level versus distance like curve C. At a distance of 20 kilometers, the dispatcher's signal shows only a loss of 50 decibels. The remaining signal level is entirely adequate for operation of the carrier-phone sets, since the allowable transmission loss is about 70 decibels. Similarly, for a motor operator transmitting on the trolley wire 20 kilometers away, a 45-decibel loss occurs at the dispatcher's phone connected to the dedicated wire as shown in curve B.

The figure further illustrates that the more difficult situation occurs when both transmission and reception take place on the trolley wire; namely, the limiting 70-decibel loss is reached at a distance of only 16 kilometers, as shown in curve D. This consequence is not serious because vehicle-to-vehicle communications are required primarily between closely spaced vehicles. On the other hand, a dispatcher connected to the dedicated wire will always be able to reach vehicle operators, and the operators will always be able to reach the dispatcher.

The dedicated wire is installed with no direct connection to the trolley wire-rail. A strong electromagnetic coupling exists between the dedicated wire-rail and the trolley wire-rail, simply because of their physical proximity. Thus, the dedicated wire is not jeopardized by direct coupling to the high-voltage trolley wire.

The theory indicates that excellent results should be obtainable with a dedicated wire. The dedicated-wire concept permits installation of a transmission line with controlled branching that can be terminated to avoid standing-wave patterns. The price paid is that the wire has to be installed and maintained in a haulageway. Theoretically, this dedicated wire can be as close as 3 inches to the rib and other conducting members in the mine without the signal being severely attenuated. The wire can be strong, such as

copperweld wire. Limited experiments in mines have so far supported theoretical conclusions, and large-scale tests in an operating coal mine are planned for the near future to confirm the conclusions.

Applying either of these two techniques to the trolley carrier-phone communication systems in operating coal mines should make otherwise marginal systems fully operational, and presently inadequate coverage adequate. Thus, the problems in obtaining and maintaining adequate trolley carrier-phone coverage in a coal mine can be overcome.

INSTALLATION AND MAINTENANCE GUIDELINES

The second program is concerned with guidelines applicable to trolley carrier-phone systems. These guidelines cover installing equipment both on mine vehicles and at the dispatcher's location, converting the trolley wire into a functional carrier-frequency-transmission line, checking the performance of carrier-phone systems, and using practical portable test equipment for system testing.

Figures 5-7 are sample illustrations from the installation guidelines. Two guidelines discuss and illustrate good installation practices; the third guideline treats testing and trouble-shooting of carrier phones. Specific test equipment is recommended in the guidelines.

Signal Mapping

Rather than offering detailed comments on the contents of each of these guidelines, we focus on just one aspect of the guideline concerned with converting the trolley wire-rail into an operating transmission line. In the preceding discussion on the causes of poor performance, the extremely poor propagation characteristic of the trolley wire-rail was cited. Apparently, this poor propagation dominates in determining the performance of trolley carrier-phone systems. Thus, it is appropriate that serious consideration be given to ascertaining the characteristics of the trolley wire-rail. What is typically available now is only a "yes" or "no"; that is, the phones work or they do not work.

As part of this guideline, signal and noise mapping is treated. It suggests that the signal and noise strengths be measured. The procedure is simple. The dispatcher's transmitter is used as the signal source, and both the strength of the signal along the haulageway and the corresponding noise level are measured. This measurement is conveniently made by equipping a jeep with a tuned voltmeter (fig. 8). The jeep moves along the haulageway, stopping at intervals of about 2,000 feet. The operator calls the dispatcher and asks for a 10-second keying-on of his transmitter. The received voltage on the tuned voltmeter is noted on a mine map, and the noise level is also noted. This map then identifies regions of the mine where excess noise may be the problem, as well as regions where weak signal levels cause problems. The map also aids in identifying the key bridging loads, branches, or unterminated lines that can cause problems. This signal- and noise-mapping process is the

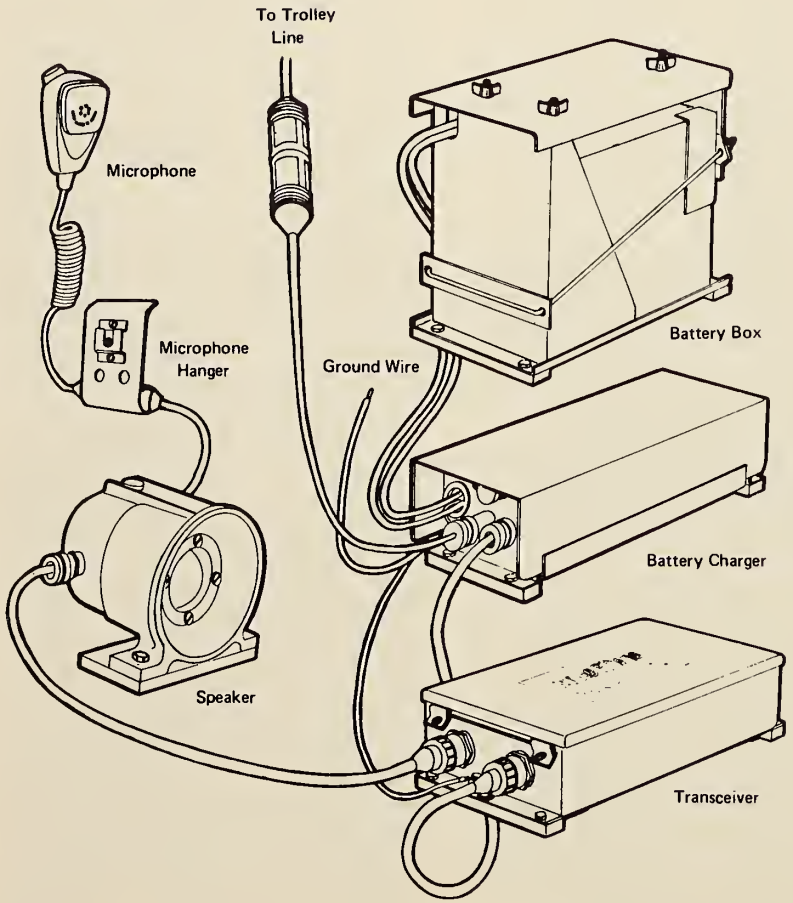

FIGURE 5. - A carrier phone (sample illustration from guidelines).

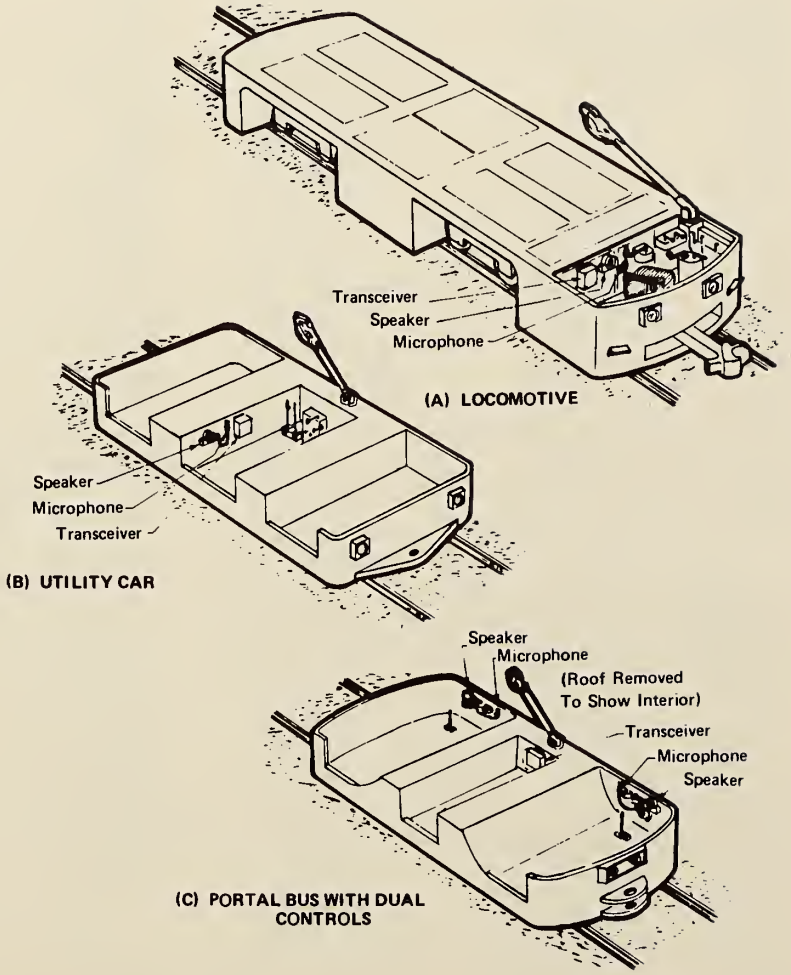

FIGURE 6. - Equipment installation on vehicles (sample illustration from guidelines).

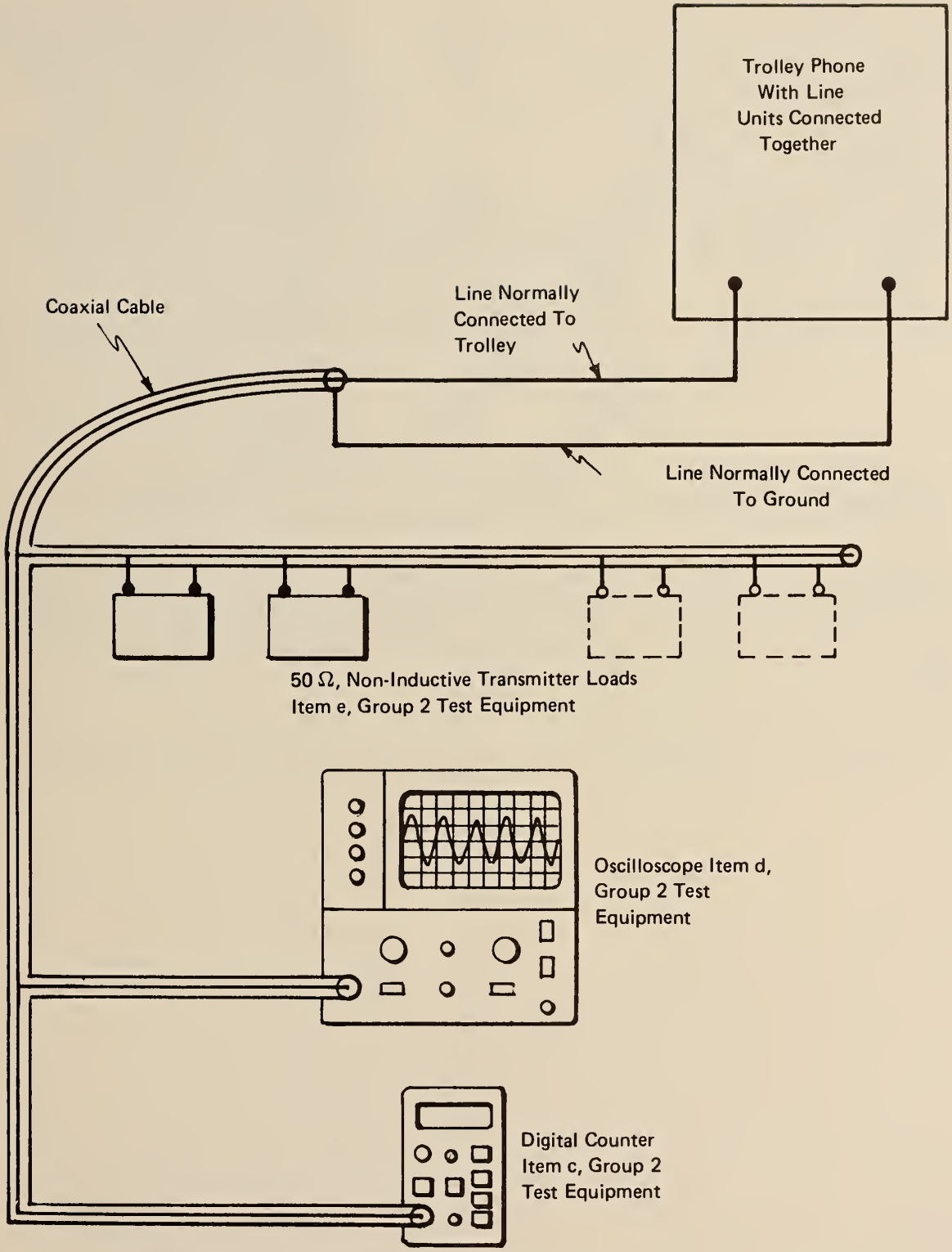

FIGURE 7. - Bench test setup (sample illustration from guidelines).

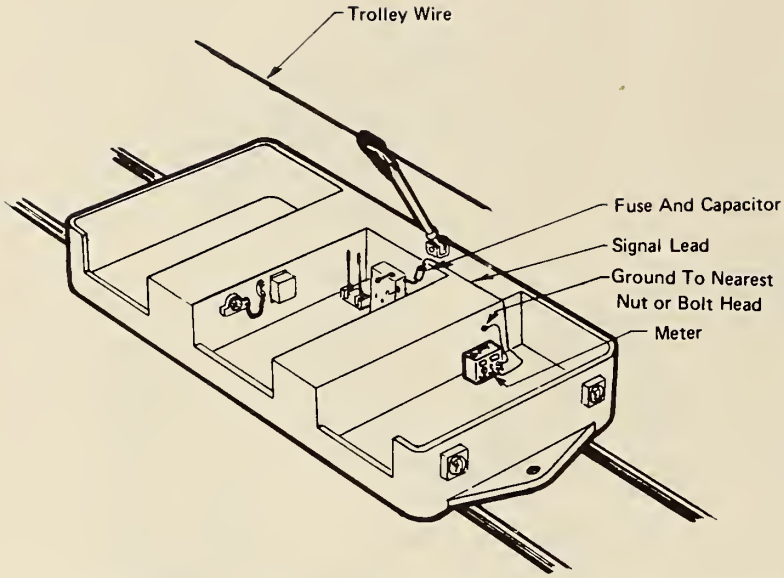

FIGURE 8. - Tuned voltmeter installed in jeep.

key to identifying the major causes of poor signal reception in a particular mine.

Once the probable source of difficulty has been identified, the remaining part of the guideline can be consulted to determine possible ways of treating the problem. For example, if a rectifier is blocking signal propagation, the guidelines provide three different ways to treat the rectifier to reduce the blockage.

CONCLUSION

Two means suggested of overcoming the signal-propagation deficiencies of the trolley wire-rail as it is typically found in coal mines are the low-impedance line and the dedicated wire. Guidelines to aid in installing and servicing trolley carrier-phone systems now exist. These guidelines provide helpful techniques for improving trolley carrier-phone systems.

BIBLIOGRAPHY

1. Hill, D. A., and J. R. Wait. Analysis of Radio Frequency Transmission Along a Trolley Wire in a Mine Tunnel. IEEE Trans. on Electromagnetic Compatibility, v. EMC-18, No. 4, November 1976, pp. 18:1-18:16.

2. Lagace, R. L., A. G. Emslie, M. F. Roetter, R. H. Spencer, and Consultants. Survey of Electromagnetic and Seismic Noise Related to Mine Rescue Communications. Volume I. Emergency and Operational Mine Communications. BuMines Open File Rept. 38(1)-74, 1974, 512 pp.; available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 235 069/AS.

3. Spencer, R. H. Improvements for Mine Carrier Phone Systems. Arthur D. Little, Inc., Final Report--Task 1, Task Order 2, Bureau of Mines Contract H0346045, 1977, 54 pp.; available for consultation at the Bureau of Mines Mining and Safety Research Center, Pittsburgh, Pa.

4. Spencer, R. H., P. F. O'Brien, and D. L. Jeffrey. Guidelines for Trolley Carrier Phone Systems. Arthur D. Little, Inc., Final Report, Bureau of Mines Contract J0166010, April 1977; available for consultation at the Bureau of Mines Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.

5. Wait, J. R., and D. A. Hill. Radio Frequency Transmission via a Trolley Wire in a Mine Tunnel With a Rail Return. IEEE Trans. on Antennas and Propagation, v. AP-25, No. 2, March 1977, pp. 25:1-25:12.

LEAKY-FEEDER ULTRAHIGH-FREQUENCY RADIO

by

Robert L. Chufo[1]

SUMMARY

An underground communication system developed by the Bureau of Mines has been implemented in a magnetite ore block-caving operation. Two-way voice communications have been established with trackless vehicles and roving personnel. A unique system of ultrahigh-frequency and very-high-frequency repeaters, combined with a leaky-feeder transmission line, offers operational and emergency features not previously found in mine communication systems. Evacuation alarming, personnel paging, fan-hole-drill-operator communications, and maintenance- and safety-vehicle radio are features of the installation. The system does not require a dispatcher and operates during power failure.

BACKGROUND

Bethlehem Mines Corp., a subsidiary of Bethlehem Steel Corp., owns and operates Grace mine, near Morgantown, Pa. The underground iron ore mine was developed for five levels, utilizing conventional electric mine locomotives equipped with carrier-current-operated radios to control movement, order repairs, and expedite production. A change in the mining method at the sixth level (2,400 feet underground) resulted in rail haulage being replaced by rubber-tired, diesel-powered vehicles. It quickly became apparent that the low-frequency (LF) carrier radios were no longer useful as a means of communications on the new equipment.

As a result, the Federal Bureau of Mines and the Bethlehem Mines Corp., under a cooperative agreement, developed a mine communication system that would serve the needs of the personnel and vehicles involved in the block-caving operation. These needs were determined through a systems study of the mining activity. As well as satisfying both present and anticipated communication needs of the mine, the system was designed to match the installation and maintenance capabilities of the mine personnel.

DESCRIPTION OF SYSTEM

In addition to providing communication to personnel carriers, maintenance and production vehicles, and the ambulance (fig. 1), the system had to provide communications for roving miners, foremen, fan-hole-drill operators, and supervisors. Communication requirements were satisfied by using (1) ultrahigh-frequency (UHF) wireless radio, (2) a radiating coaxial Radiax^{R} cable "leaky" transmission line to carry the signal throughout the haulage and subdrifts of

[1]Electrical engineer, Pittsburgh Mining and Safety Research Center, Bureau of Mines, Pittsburgh, Pa.

FIGURE 1. - UHF mobile radio mounted on underground ambulance.

the mine, (3) interconnected very-high-frequency (VHF) and UHF repeaters, (4) portable transceivers, and (5) vehicle-mounted transceivers.

A Radiax cable (fig. 2) is a special type of coaxial cable that allows radio-frequency signals to leak into and out of itself. Figure 3 shows how the field strength varies in the immediate vicinity of the cable. With the cable as a medium, signals can be transmitted to and received from mobile units in its immediate vicinity, and hence the cable is ideally suited for haulage applications. In effect, the cable provides a tunnel of signal strength (fig. 4). The signal strength attenuates along a cable run, but repeaters are used to boost signal strength. "Dead-end" lengths of cable are terminated with antennas to extend communication range. Power splitters allow the cable to have side branches. Figure 5 shows the basic cable hardware--an antenna, a power divider, and the cable itself.

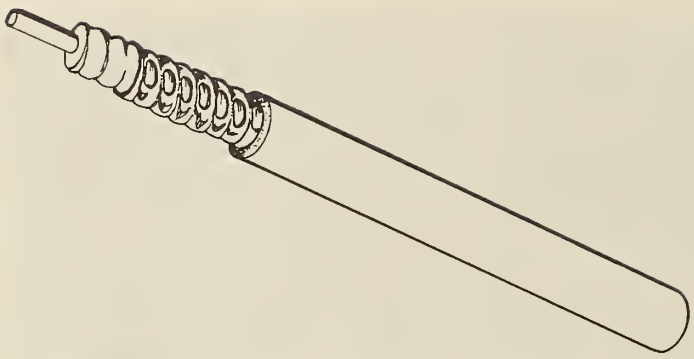

FIGURE 2. - Cutaway view of Radiax cable.

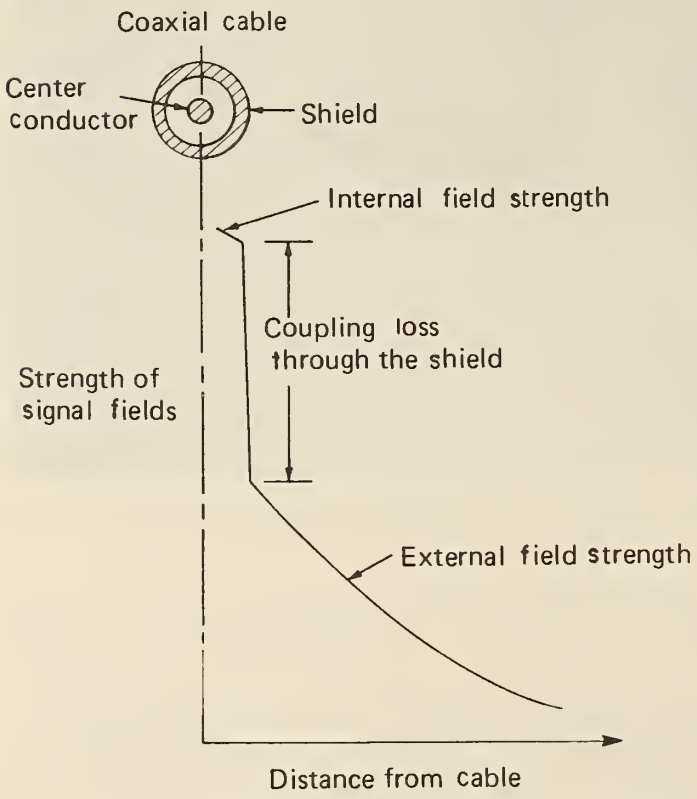

FIGURE 3. - Principle of operation of Radiax-guided wireless radio system.

Figure 6 shows the mine map, including the haulageways and other points the system has to serve, and figure 7 shows the extent of the radiating cable installation. There are 11,000 feet of 7/8- and 1/2-inch Radiax cable in the system. Two repeaters are required to compensate for the loss, as well as to provide adequate power levels for future system expansion. The system is designed so that a third repeater can be added as the mine expands without altering the present configuration.

The specifications recommended that the cable be supported every 5 feet. To avoid installing 2,000 anchors in the rock, a 3/16-inch steel messenger wire was attached at 20-foot intervals to roof-bolt-supported T-bars (fig. 8). The cable was then strapped to the messenger wire with standard cable ties.

A vehicle-mounted work platform, which could be mechanically raised or lowered and was equipped with a frame for supporting cable reels, facilitated cable installation. The factory cut the cable to predetermined lengths, installed connectors, and tagged the cable with location identifiers. Some areas were so far removed from the installed cable that radio transmissions could not be established. This was overcome by inserting a stub cable with one end connected through a power divider to the main cable; the other end terminated in an antenna located within several hundred feet of the desired working area.

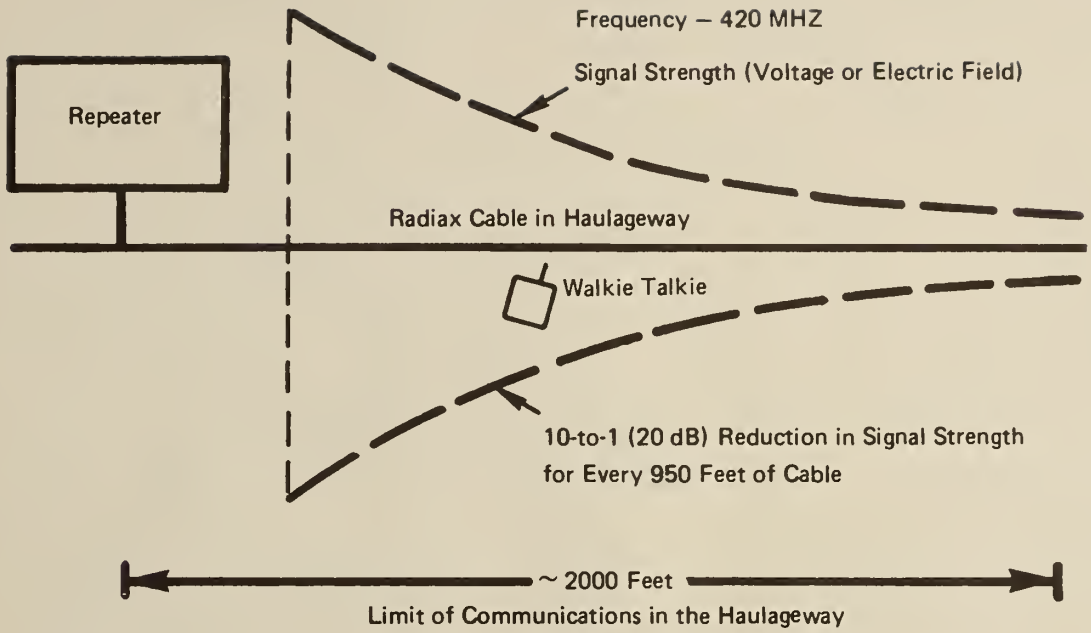
Frequency – 420 MHZ
Signal Strength (Voltage or Electric Field)
Repeater
Radiax Cable in Haulageway
Walkie Talkie
10-to-1 (20 dB) Reduction in Signal Strength
for Every 950 Feet of Cable
~ 2000 Feet
Limit of Communications in the Haulageway

FIGURE 4. - Two-way communication range for Radiax-guided wireless radio system.

FIGURE 5. - Basic cable hardware—antenna, power divider, and cable.

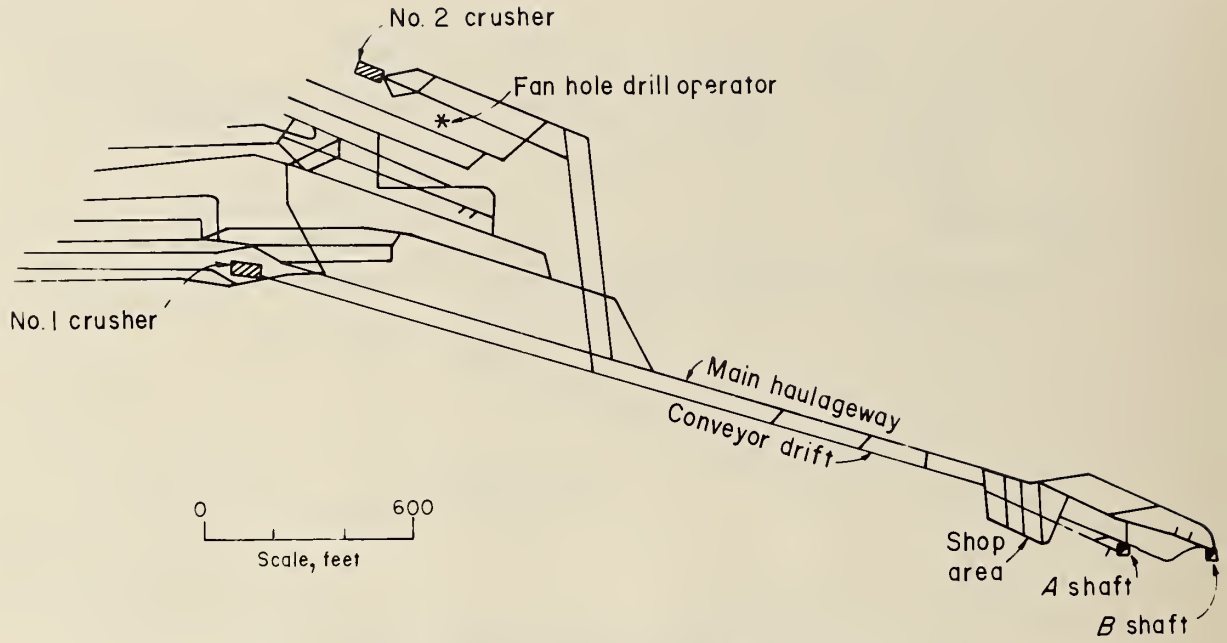

FIGURE 6. - Underground map of level 6 of Grace mine.

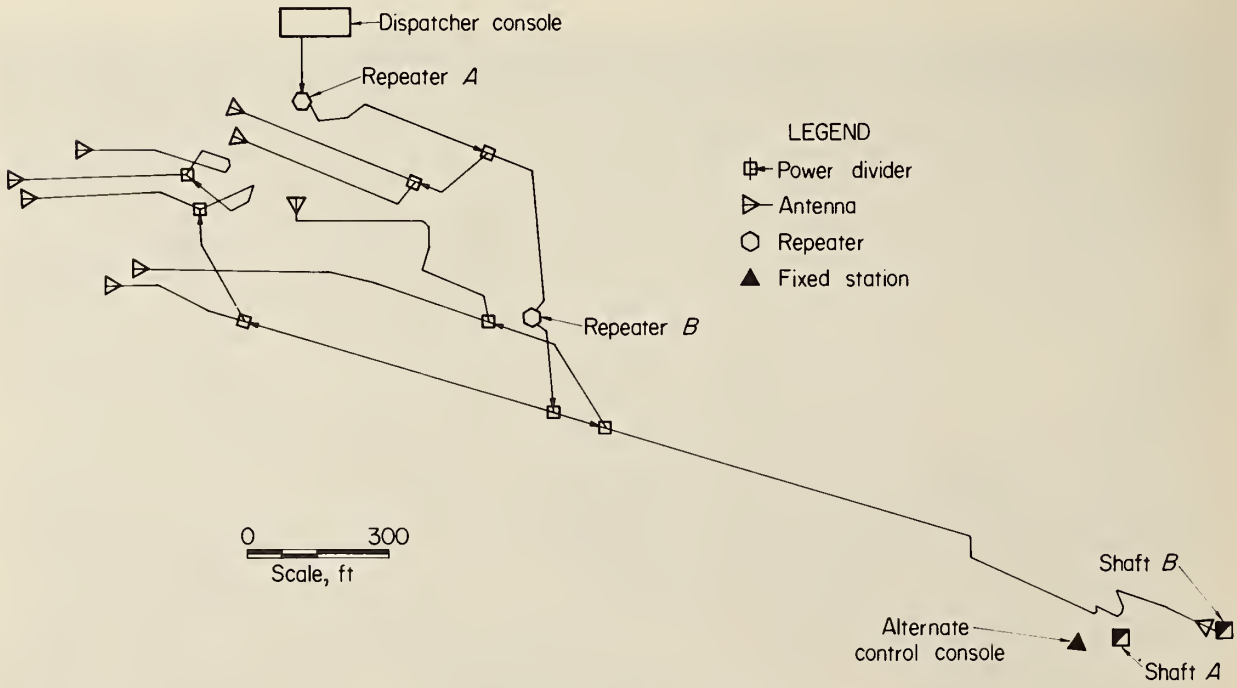

FIGURE 7. - Radiax layout.

FIGURE 8. - Radiax cable installation on messenger wire.

The system of cables effectively wired the mine for UHF signals between portable and mobile units. Each repeater (fig. 9) can receive and transmit signals on the cable at both UHF and VHF. VHF signals are used on the cable as a communication link between the repeaters (fig. 10), while UHF is used for the communication link to and from the portable and mobile units. Radios in the vicinity of the same repeater can communicate via that repeater, but radios located in different zones of the mine must communicate through both repeaters. UHF signals received by the repeater in one zone are transferred back to the VHF band and are transmitted on the Radiax cable to radios in the area of the mine served by the second zone repeater.

The repeater control console (fig. 11) may be either manned or unmanned; no one is needed to operate the system. Paging can be initiated at the console to send private messages to portable radios.

FIGURE 9. - UHF/VHF repeater installed in cross drift.

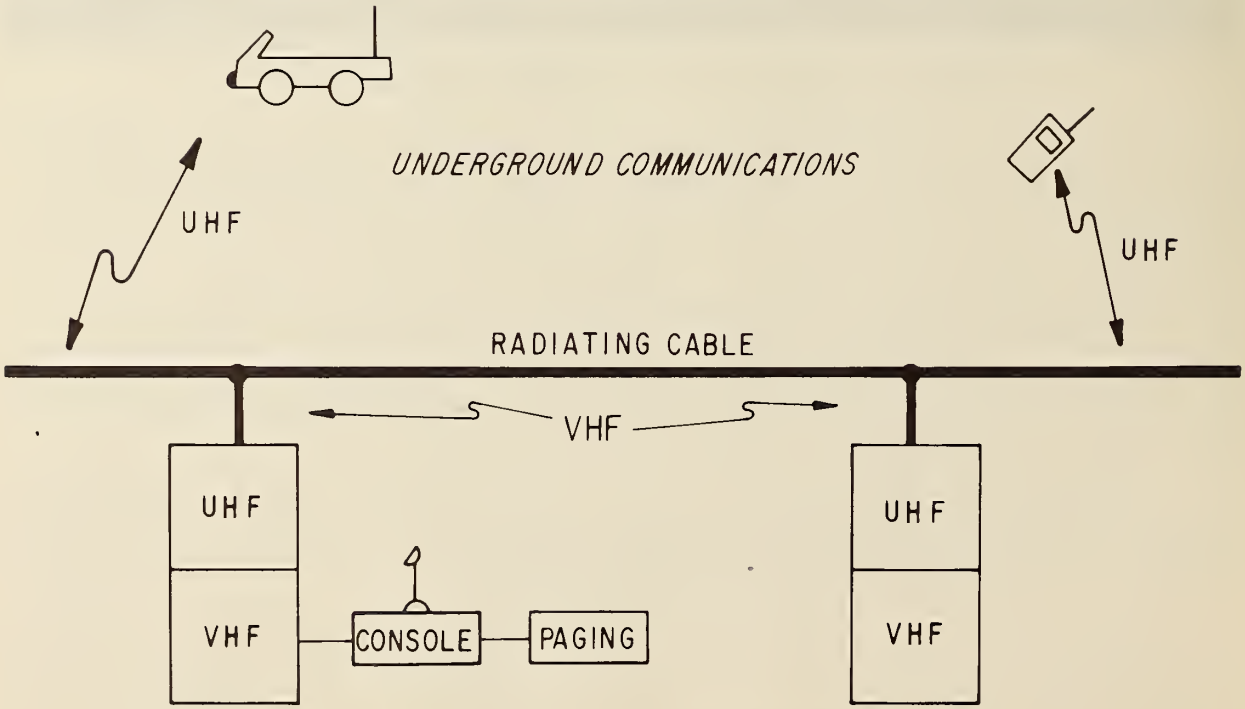

FIGURE 10. - UHF/VHF repeater system.

FIGURE 11. - Repeater, control console, and page encoder at No. 2 crusher room.

The alternate control station is shown in figure 12. This small console is connected by wire line to an intercom unit in the surface guardhouse (fig. 13). The guard can access the system as if he/she were stationed at the console.

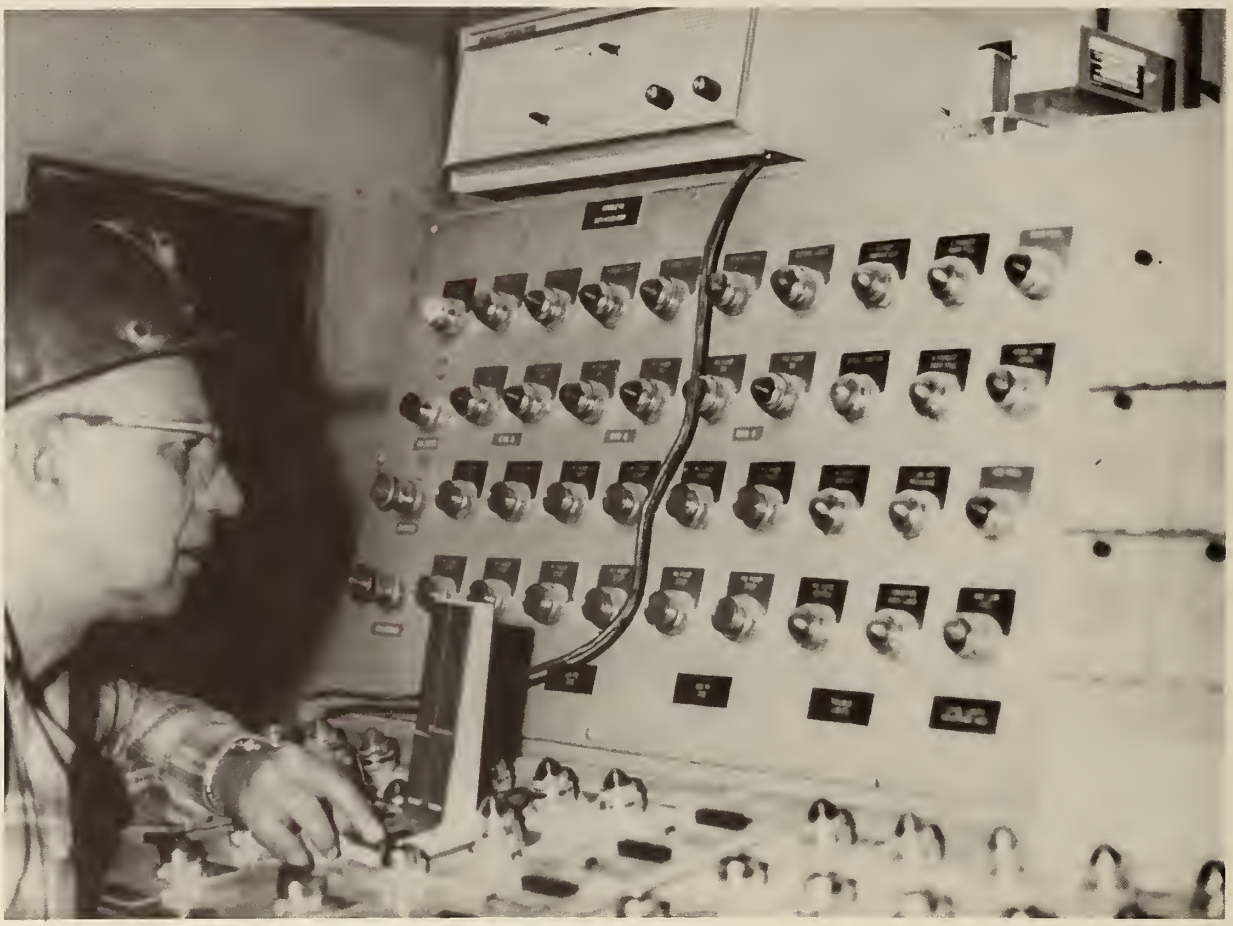

FIGURE 12. - Console monitoring station at conveyor operator's console.

Figure 14 shows a portable unit being used by a fan-hole-drill operator working alone in a remote area of the mine. Without communications, two persons would be required at this station. In this case, the operator routinely checks in at half-hour intervals to report on the operation of his/her equipment and well being. A portable HT 220 radio is attached to his/her belt, and he/she wears a noise-reducing headset with speakers installed in both "earmuffs." A similar single earmuff contains a microphone which is spoken into to contact the console monitor station (fig. 12). Fan-hole-drill operators are not located in the immediate vicinity of the cable, but operate in drifts 200 to 500 feet from the nearest cable installation. Nevertheless, they are still able to transmit signals to and receive signals from the cable and thus communicate with the console, which is manned by the conveyor operator.

FIGURE 13. - Remote control of underground console provided by intercom unit in surface guardhouse.

FIGURE 14. - Fan-hole drill operator with noise-reducing speaker-microphone and belt-mounted radio.

PROGRESS TO DATE

Grace mine has outfitted an underground radio shop with the necessary service equipment to maintain the communication system. A full-time radioman with a second-class license from the Federal Communication Commission (FCC) has been trained in system installation, operation, and maintenance. Reliability of the UHF-VHF system, in service since October 1975, has been excellent.

Since the installation in the Grace mine, six other mines have installed commercial leaky-feeder systems to meet critical communications needs. The mining companies and the communication needs met by the systems are Cedar Coal Co., battery-operated haulage; Dravo Lime Corp., slope; AMAX-Henderson Project, 9.5 miles of tunnel; Maple Meadows Mining Co., battery-operated haulage; Clinchfield Coal Corp., longwall; Alwinsal Potash Co., all-purpose, 5-mile run.

BIBLIOGRAPHY

1. Chufo, R. L., and P. L. Vancura. The Installation, Operation and Maintenance of an Underground Mine Wide Radio System. IAS Conf. Proc., 1976, pp. 1196-1202.

2. Emslie, A. G., R. L. Lagace, and P. F. Strong. Theory of the Propagation of UHF Radio Waves in Coal Mine Tunnels. IEEE Trans. on Antennas and Propagation, v. AP-23, No. 2, March 1975, pp. 192-205.

3. Lagace, R. L., M. L. Cohen, A. G. Emslie, and R. H. Spencer. Propagation of Radio Waves in Coal Mines. Arthur D. Little, Inc., Final Report--Task F, Task Order No. 1, Bureau of Mines Contract H0346045, October 1975, 172 pp.; available for consultation at the Bureau of Mines Mining and Safety Research Center, Pittsburgh, Pa.

REMOTE CONTROL OF CIRCUIT BREAKERS

by

Harry Dobroski, Jr.[1]

SUMMARY

The movement of off-track mining equipment on electric rail haulageways is a hazardous undertaking, particularly when there is less than 12 inches of clearance between the equipment and an energized trolley or feeder wire. The Bureau of Mines is developing a remote-control system for shutting down the circuit breaker that provides trolley power. Such a control system will permit immediate shutdown of the trolley power by a member of the moving crew if the equipment contacts the trolley wire or feeder.

BACKGROUND

In underground coal mining, off-track mining equipment often has to be moved in an entry with less than 12 inches of clearance between the equipment and an energized trolley or feeder line. Under such circumstances, the equipment could easily come in contact with the trolley wire, thereby creating a ground fault. The current in this ground fault is limited by the (1) size and length of the trolley wire, (2) contact resistance between the equipment and the trolley wire, and (3) contact resistance between the equipment and the track. Thus, all too often the ground-fault current will be large enough to be dangerous, but not large enough to open the circuit breaker protecting the trolley wire. This is because most of the circuit breakers used to protect trolley wires in underground coal mines rely on an electromechanical overcurrent relay that is set high enough to permit normal-load currents to flow. Normal-load current often exceeds 3,000 amperes on a 275-volt, direct-current trolley system. If a ground fault does occur and the circuit breaker protecting the trolley wire does not open automatically, the circuit breaker can still be opened manually by a safety person at the breaker, who is in voice communication with the people making the move.

On October 21, 1973, the U.S. Department of the Interior promulgated regulations (30 CFR 75.1003-2) to control the movement of off-track mining equipment when there is less than 12 inches of clearance between an energized trolley wire and the equipment. These regulations include the following provisions:

1. Power must be supplied from outby the equipment being moved;

2. The overcurrent relays at the circuit breaker that protect the trolley wire must be set to no more than one-half the maximum short-circuit current;

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3. A miner in direct communication with the workers moving the equipment must be stationed at the first outby circuit breaker; and

4. No person shall be permitted inby the equipment being moved, on the same split of air, except those persons moving the equipment.

These Federal regulations (and, in some cases, various State regulations) have reduced the hazards associated with moving off-track mining equipment in an entry where there is less than 12 inches of clearance between the equipment and the energized trolley wire. However, in spite of these precautionary regulations, serious hazards still exist. If the breaker fails to open quickly and reliably, serious damage or even death could occur before a verbal message could be given to the safety person at the breaker location. Clearly, these hazards could be further reduced by the development of a portable, remotely controlled circuit-breaker system that would allow the equipment movers to open the breaker at will and to control its setting.

DISCUSSION OF SYSTEM

A transmitter and receiver that use the trolley line to control the circuit breaker are being developed. The transmitter is located on the locomotive that is pulling the off-track equipment; a receiver is mounted on a flat car, along with a portable circuit breaker. In addition, the receiver must continuously receive a signal from the transmitter for the circuit breaker to remain closed. The loss of this signal either by a failure in the transmitter or receiver, a short to the trolley line, or any other reason will cause the circuit breaker to open. In addition, the receiver system has been designed to adjust the current setting, or "trip point," of the circuit breaker by a command from the transmitter. The locomotive transmitter can even be shut off remotely if necessary, thus allowing a worker off the locomotive to open the breaker. A voice communication system, operating on its own channel, is also built into the transmitter and receiver. Therefore, under the worst condition, a worker at the locomotive could verbally tell a worker at the breaker to open it, if the need arose. A block diagram of the proposed system is shown in figure 1.

Although it is possible to equip each and every circuit breaker in a given mine with a remote-control system, it is not practical to do so. Since the regulations mentioned previously (30 CFR 75.1000) state that trolley and feeder wires shall be provided with cutout switches at intervals of not more than 2,000 feet and near the beginning of all branch lines, it is possible to

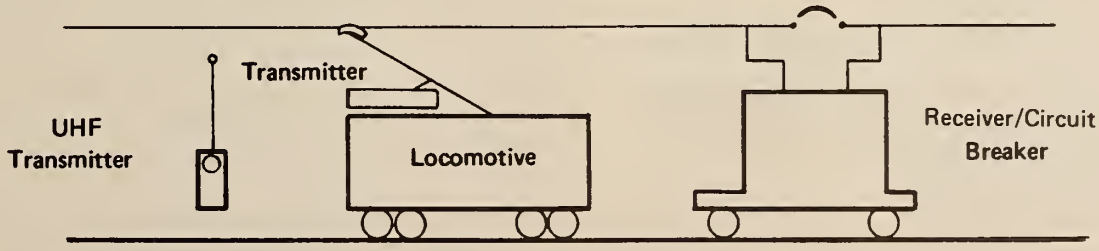
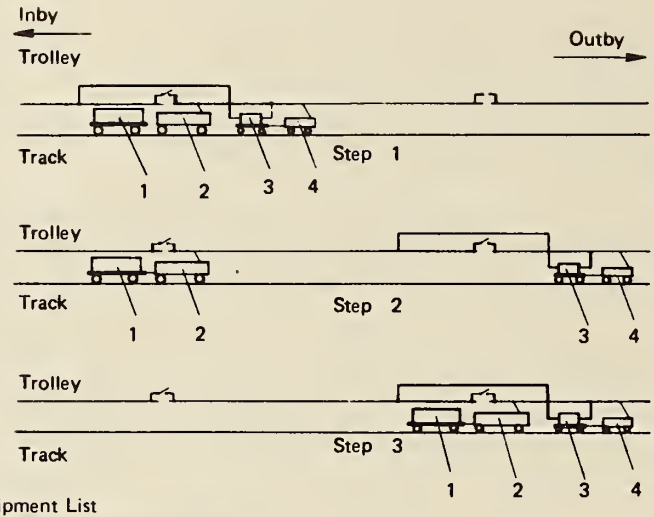


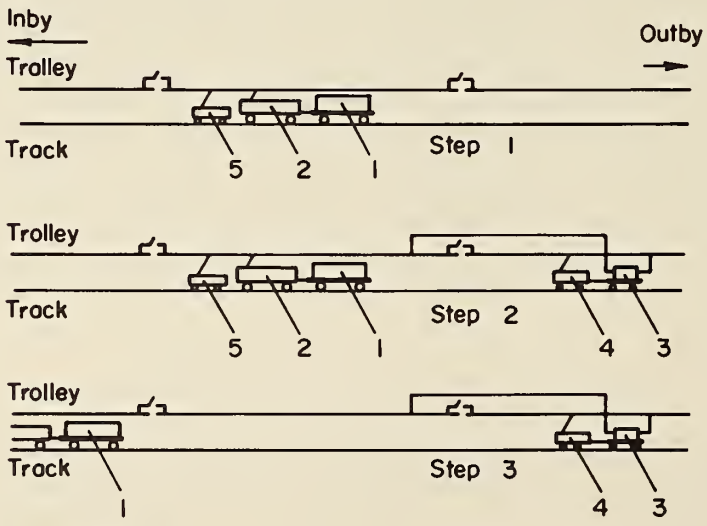
FIGURE 1. - Diagram of proposed system.



Equipment List

1. Off-Track Mining Equipment Mounted on a Flat Car
2. Locomotive With the Remote Control Unit
3. Circuit Breaker And The Receiver Unit Mounted on a Flat Car
4. Small Utility Jeep

FIGURE 2. - Pulling a piece of off-track mining equipment out of the mine when using a portable circuit breaker.



Equipment List

1. Off-Track Mining Equipment Mounted on a Flat Car
2. Locomotive With The Remote Control Unit
3. Circuit Breaker And The Receiver Unit Mounted on a Flat Car
4. Small Utility Jeep
5. Small Utility Jeep

FIGURE 3. - Pulling a piece of off-track equipment into the mine when using a portable circuit breaker.

isolate and protect any section of trolley line no more than 2,000 feet long. A more practical solution is to use a portable, remotely controlled circuit breaker that goes with the equipment being moved. Such a system is shown in figure 2, which shows a piece of off-track mining equipment being moved out of a mine.

In the first step, the locomotive operator advances the locomotive until the trolley pole is positioned on the outby side of the dead block and the off-track mining equipment still remains on the inby side of the dead block, as required by law. At this point, the locomotive operator removes power from the remote control unit, opening the remote circuit breaker.

Next, the jeep operator, a licensed electrician, disconnects the remotely controlled circuit breaker from the trolley line and pulls it past the next trolley disconnect switch (maximum distance of 2,000 feet). He then opens the disconnect switch and connects the circuit breakers around it.

Finally, the locomotive operator receives permission from the operator of the jeep to advance towards the next outby disconnect switch. The locomotive operator then sets the remotely controlled breaker to the proper trip point and closes it. The locomotive can now pull the off-track mining equipment

toward the outby disconnect switch. During this move, the energized trolley wire above the equipment is protected by the portable remotely controlled circuit breaker, which has an overcurrent setting chosen by the locomotive operator. The process is repeated as many times as necessary to remove the equipment from the mine.

A similar procedure is followed in moving the equipment into the mine (fig. 3). First, the locomotive operator advances the locomotive until the trolley pole and off-track mining equipment are on the inby side of the dead block. At this point, the locomotive operator gives permission to the operator of the No. 4 jeep to advance the circuit breaker.

Next, the operator of No. 5 jeep opens the next inby disconnect switch and returns to the locomotive. The operator of No. 4 jeep, a licensed electrician, disconnects the circuit breaker, advances toward the locomotive, and connects the circuit breaker around the disconnect switch at the locomotive.

Finally, the locomotive operator sets the trip point on the remotely controlled circuit breaker and closes the breaker. The locomotive can now pull the off-track mining equipment toward the next inby disconnect switch. During this move, the energized trolley wire above the equipment is protected by the remotely controlled circuit breaker, whose trip point has been remotely set. The process is then repeated. Similar procedures are used to move equipment from place to place within a mine.

PROGRESS TO DATE

Interviews have been held with mining personnel and State and Federal regulatory agencies to assure that the system will meet all operational and safety requirements. Hardware fabrication is expected to start early in 1977, with off-the-shelf items used throughout the system. It is anticipated that results of the program will be available in mid-1977.

HOIST RADIO COMMUNICATIONS

by

H. Kenneth Sacks[1] and Robert L. Chufo[2]

SUMMARY

To provide an easily used and effective voice communication system for shafts as deep as 10,000 feet, the Bureau of Mines has developed a pair of small, battery-operated frequency-modulated transceivers operating at 52 kHz and weighing 13 pounds, and two specially designed toroidal signal couplers. The units were tested in a 4,500-foot shaft, and excellent communication was obtained at all levels.

This program led to the production of a second version with added features. The newer units provide the conventional bell signals, a slack-rope alarm, and shaft-inspection capability as well as two-way voice communication. Three of these systems are presently being operated in commercial mines. The techniques used have been made available to the mining industry and its suppliers.

BACKGROUND

In May 1972, a fire broke out at the 3,700-foot level of the Sunshine mine. During the rescue operations, communication at the No. 12 shaft was necessary. Although an attempt was made to establish communication using available equipment, there was insufficient time to make the needed adjustments. The existing system provided a communication range of only 1,600 feet.

Similar equipment consisting of trolley wire transceivers has been used successfully in deep shafts, but these systems are generally custom fitted to achieve reasonable performance. They are also subject to the fadeout characteristic of trolley wire communication. Moreover, the equipment is large and heavy, and thus unsuitable if a rescue capsule is needed, or if only a small cage is available.

The experience at the Sunshine mine prompted the Bureau of Mines to develop a hoist-shaft communication system. Since the program might enhance hoist communications in general, the Bureau included several features for day-to-day use.

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DISCUSSION OF SYSTEM

System Requirements

A useful hoist-shaft communication system must satisfy the requirements for communication throughout the full travel of the cage, providing voice communication from the cage to the hoistman, as well as bell signaling from the cage, especially during "man" trips; shaft-inspection communication between the inspector and the "hoistman," and a slack-rope indication. For the modern, automated shaft, signals are also required to permit selection of level, enable interface with interlocks, and jog for exact position at any level are also required.

The limited space within the cage places an operational restraint on equipment. Thus, the equipment must be small, modularized, and located in the cage so that it cannot be damaged by any of the various uses of the cage such as transporting supplies and machinery into the mine. An additional microphone-speaker station is also required when several cages are joined together.

Hardware

Figure 1 shows a block diagram of the hoist radio hardware as it would be used in a shaft. The system consists of two signal couplers and two

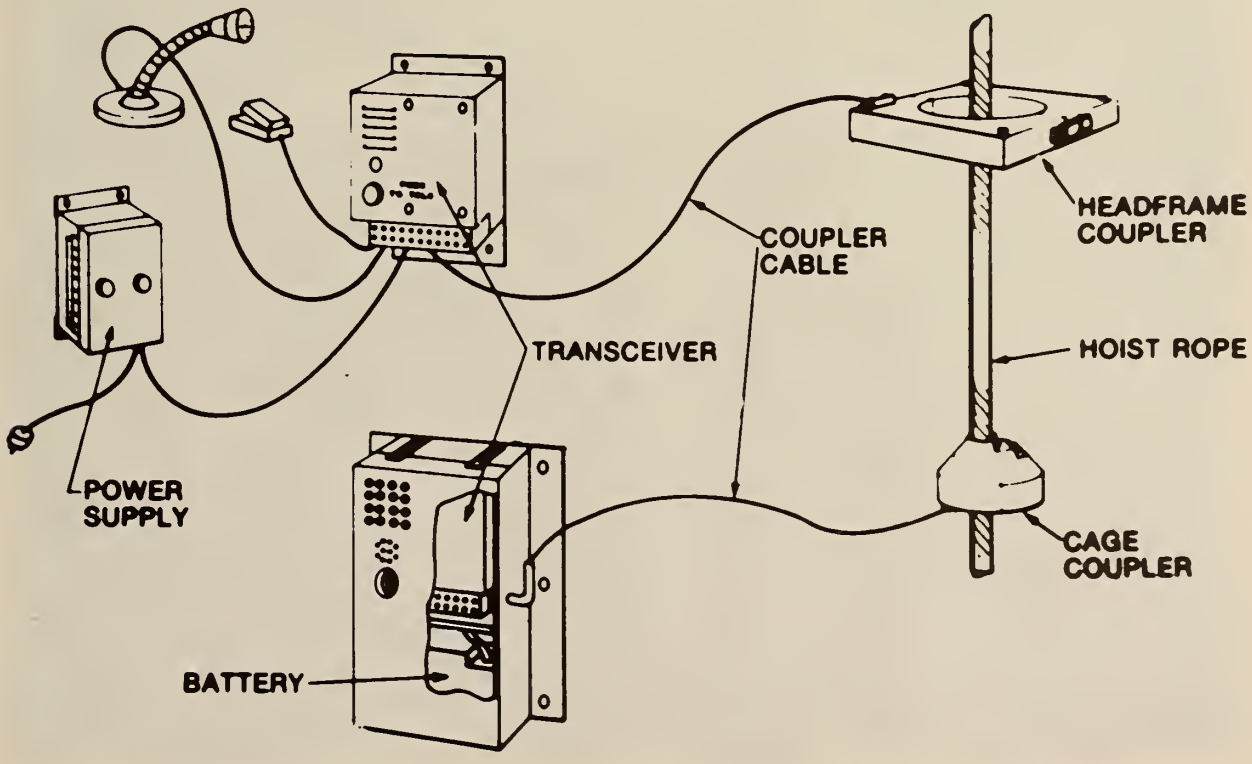

FIGURE 1. - Block diagram showing transceiver, couplers, rope, and shaft.

transceivers. Each unit is of the push-to-talk, release-to-listen design. During transmission, the sending unit feeds the coupler with a frequency-modulated (FM) carrier at 52 kilohertz (kHz). The coupler induces a signal in the rope-shaft structure, which is then picked up by the coupler of the second unit. Both couplers are electrically identical, and each operates both as a transmitting and receiving element, or "transceiver." Tests at several shafts have shown that signal losses at 52 kHz are small, and standing wave effects, which cause signal fade, are negligible. This results in high-quality voice transmission at all levels in the shaft. The most important feature of the design is the signal coupler, which was designed to achieve the maximum signal for a given transmitter power output.

Figure 2 shows the emergency system hardware, together with a battery charger, auxiliary speaker, and carrying case. The transceiver (fig. 3) is

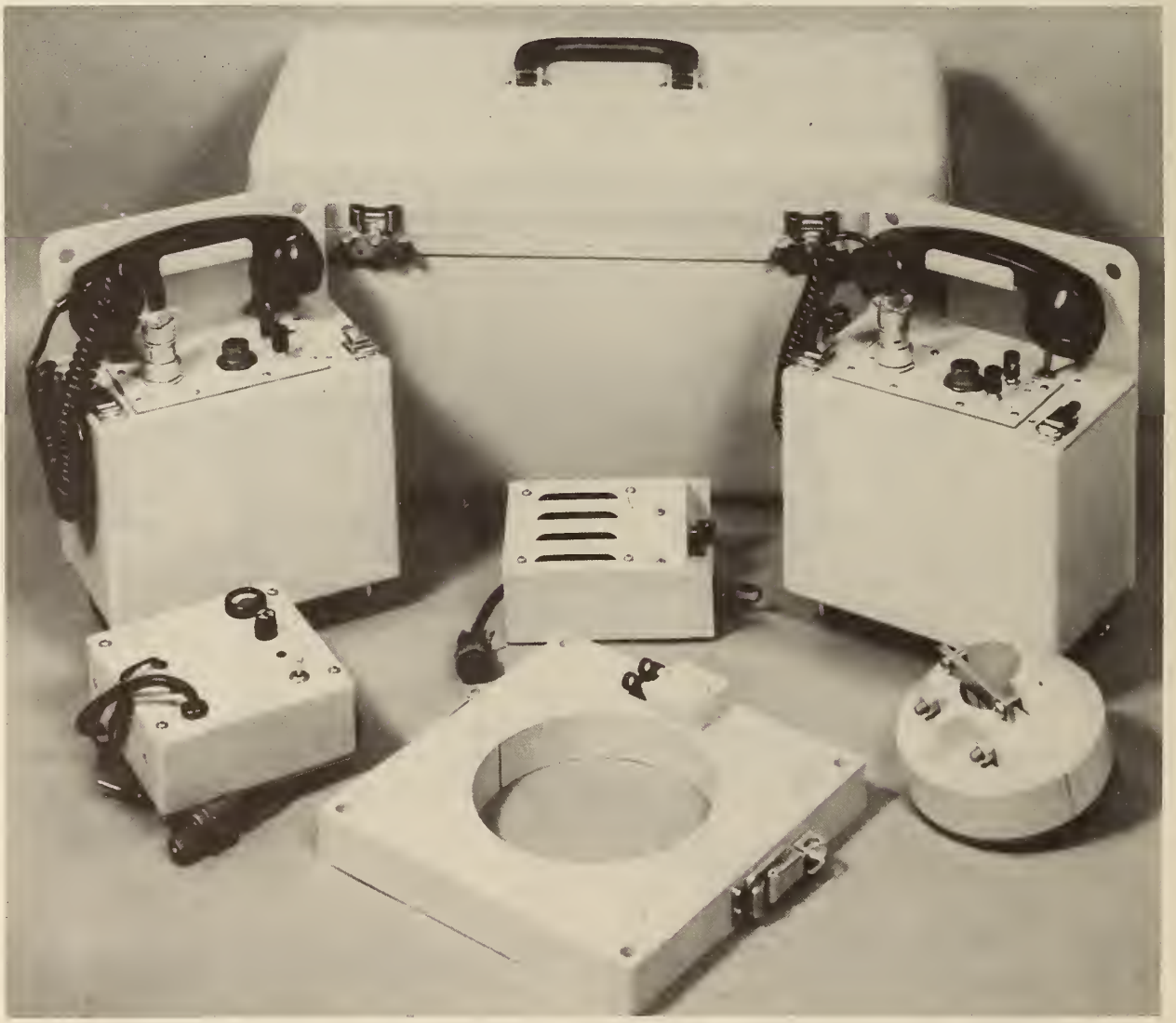

FIGURE 2. - Emergency hardware and carrying case.

FIGURE 3. - Transceiver with front-access door open.

sealed against moisture and contains its own 12-volt rechargeable, lead-acid battery. Sufficient room is available to operate off of a pair of standard 12-volt lantern batteries.

Figure 4 shows the two printed circuit cards containing all the electronics. They are environmentally protected and soldered to the unit for ruggedness. The cage coupler (fig. 5) is made of steel and acts as its own rock shield. It is designed to clamp onto the rope above the cage. A second version (fig. 6) is designed to clamp around the turned-back portion of the rope between clamps. This is necessary in installations where the coupler could be damaged by the headframe when the cage is raised to its highest point. The headframe coupler (fig. 7) is bolted above or below the headframe and has a 7-inch-diameter clearance hole for the hoist rope. The couplers are connected to their respective transceivers by any two-wire line for runs of 20 feet or less. Longer runs up to 500 feet can be made with a twisted pair of wires 18 gage or larger. Each coupler comprises two equal parts that bolt together to allow quick installation.

Additional hardware consists of an external speaker, for use on the surface, and a battery charger, which can charge both units simultaneously. The complete system is certified by the Mining Enforcement and Safety Administration (MESA) to be intrinsically safe.

Field Installation

In the field, emergency installation consists of (1) clamping the cage coupler to the rope above the cage, (2) clamping or suspending the headframe coupler at the headframe structure, and (3) connecting each coupler to its transceiver with a two-wire line.

Actual experience has shown that setup takes 15 to 30 minutes. No electronic adjustments are required. The emergency unit was designed so that, should a handset or coupler connector on the transceiver break, all connections could be made through the top panel with a screwdriver.

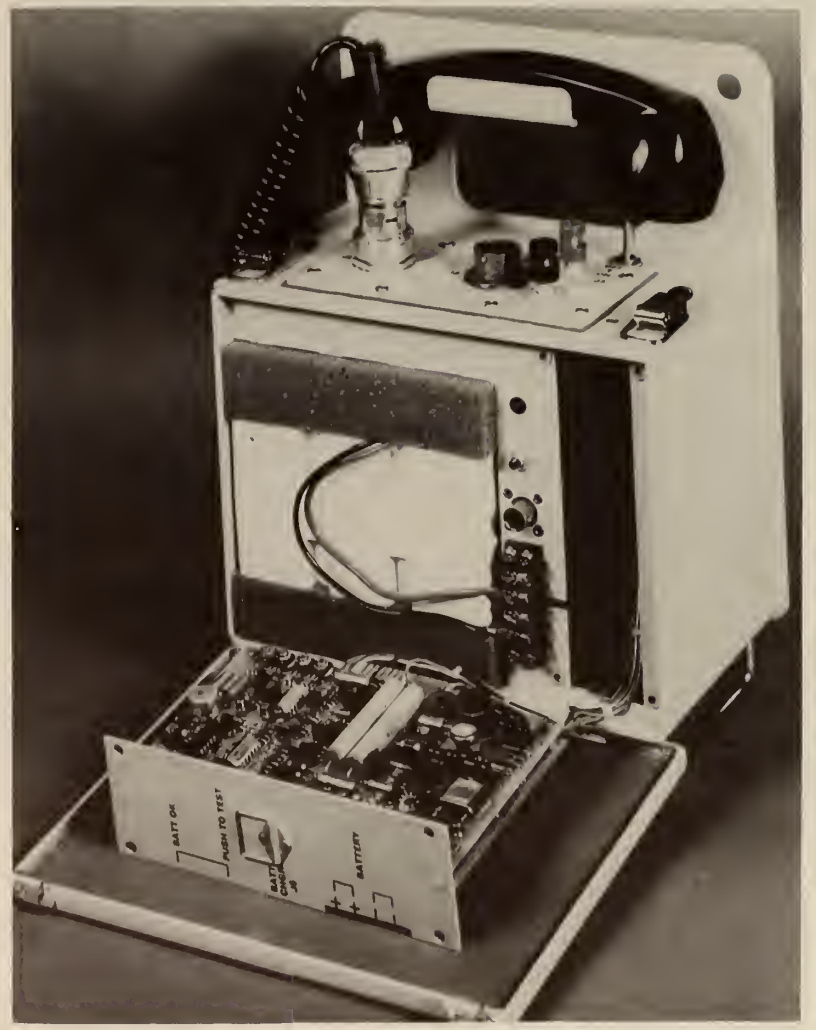

FIGURE 4. - Transceiver showing circuit boards.

FIGURE 5. - Cage coupler.

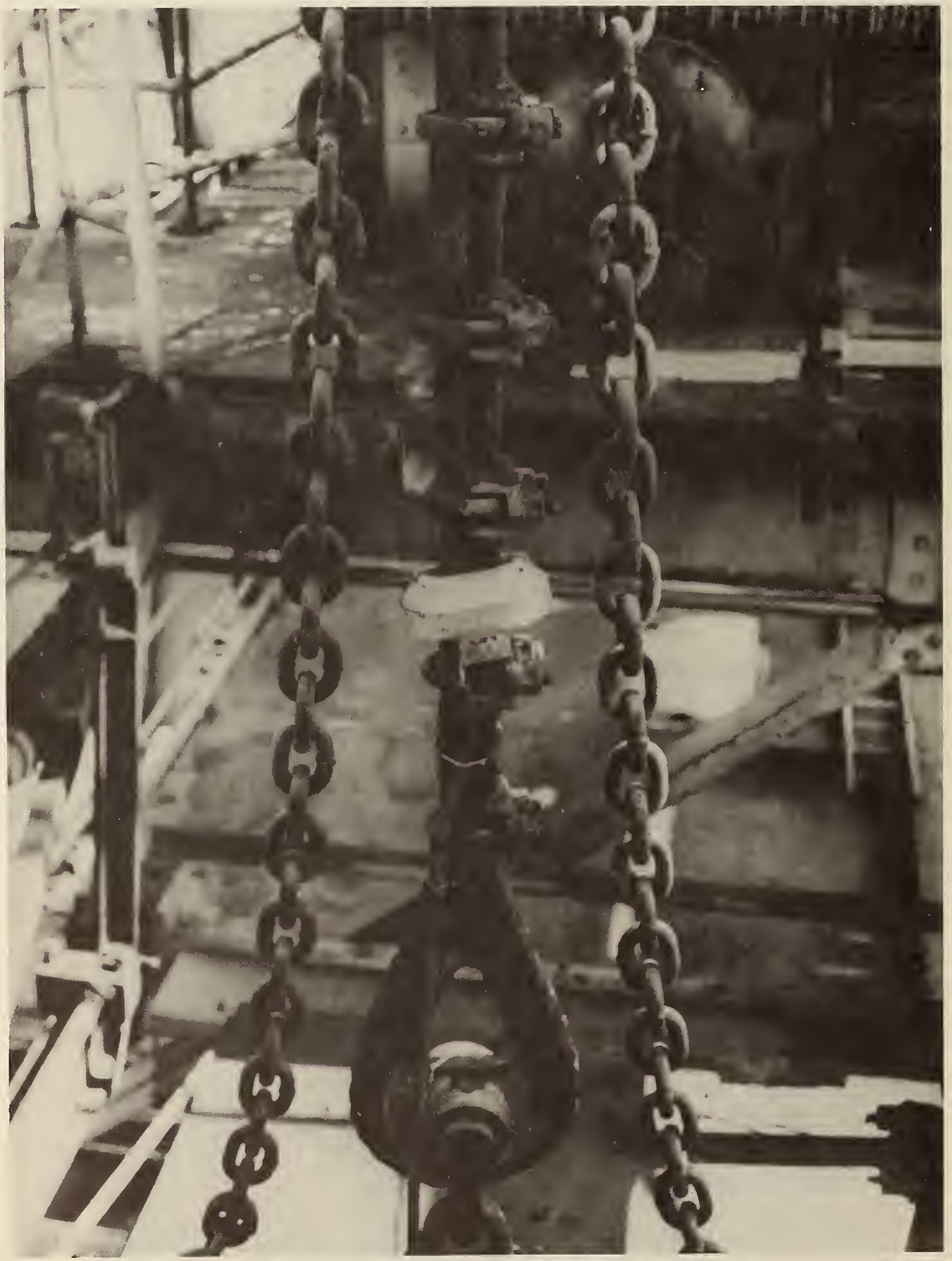

FIGURE 6. - Elliptical cage coupler.

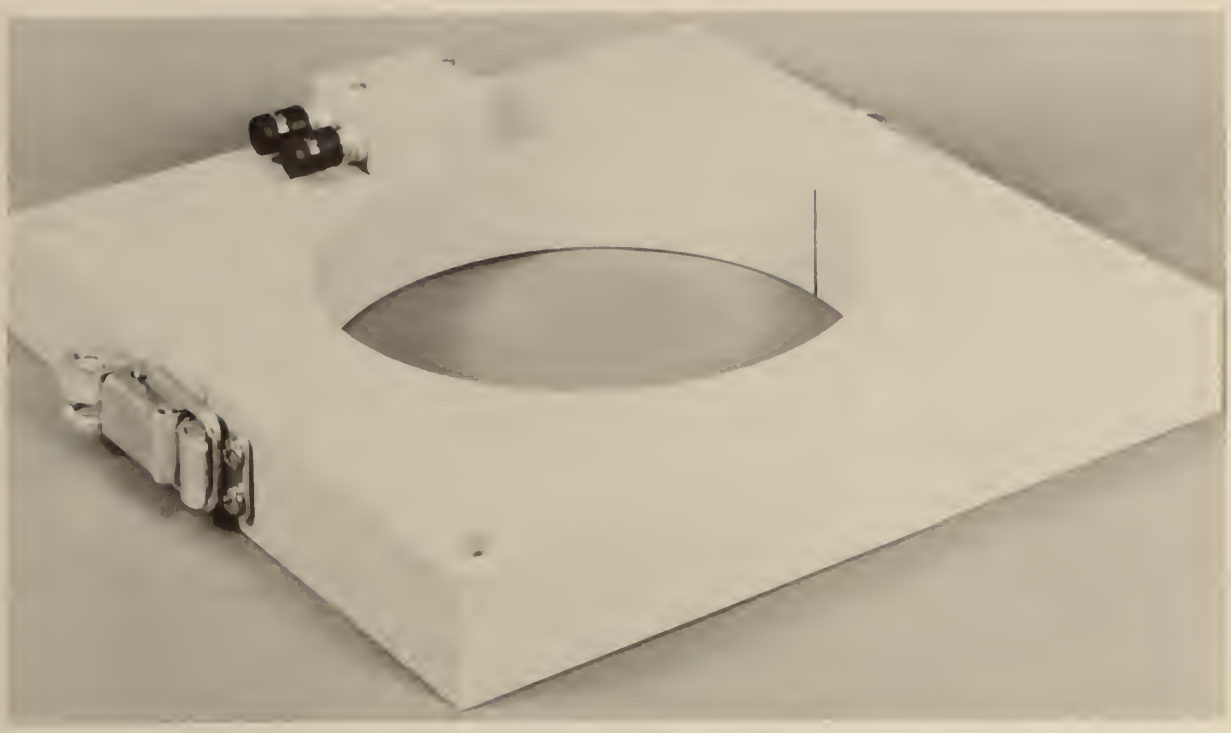

FIGURE 7. - Headframe coupler.

FIGURE 8. - Operational version.

Figure 8 shows the operational version for permanent installation, which is described in the following section. A summary of important specifications for both emergency and day-to-day operation is given in table 1.

TABLE 1. - Specifications of HCS-102 hoist system

Frequency.....52 kHz
Modulation.....Narrow band FM (12F3) + 3-kHz deviation
Supply voltage.....12 vdc, battery-operated. 3AH sealed lead-acid battery or 12-vdc dry cell, Burgess type TW2 or equivalent
Operating time.....42 hours (50% RX (receive), 50% TX (transmit) with 5AH battery)
95 hours (10% RX, 10% TX, 50% standby with 5AH battery)
Transmit power output..0.5 watts into 4.7-ohm resistive load
Frequency stability....+0.25%
Sensitivity.....10 microvolts for 20-dB quieting
Squelch.....Operates at less than 10 microvolts
Selectivity.....-60 dB at +20 kHz
Audio output.....0 dBm into handset, 2 watts into 8-ohm speaker.

Mechanical component	Size, inches	Weight, pounds
Transceiver, type 719L-3.....	12.6 x 9.4 x 5.8	13.2
Battery charger, type 962A-2.....	6.0 x 6.0 x 2.4	3.6
Speaker, type 959L-1.....	6.5 x 4.5 x 2.6	3.4
Headframe coupler, type 444E-3.....	11.0 x 11.0 x 1.0	16.4
Cage coupler, type 444E-4.....	3.4 x 6.0 diam	12.5
Carrying case, type 28N-2.....	23 x 13 x 10	10.7
Operational unit: transceiver.....	8 x 10 x 2.5	6

PROGRESS TO DATE

Initial Installations

Luck Friday Mine.--The first Bureau-developed hoist-communication hardware was a prototype system for field testing, and was installed at the Lucky Friday mine in the Coeur d'Alene mining district near Mullan, Idaho. The equipment consisted of a hoist transceiver; a control head containing the loudspeaker, microphone, and push-to-talk switch; a toroidal signal coupler; a rechargeable lead-acid battery; and interconnecting cables. The small cage, typical of deep mines in the area, prohibited installing the bulky transceiver, control head, and battery in the cage. Consequently, the equipment was installed in a steel box beneath the cage. A small box containing the speaker, microphone, and push-to-talk switch was installed in the rear corner of the cage. A remote handset outlet was installed above the cage, at the monkey deck, to provide a connection for the shaft-inspection handset (fig. 9). Also mounted above the cage was the slack-rope alarm, which senses the rotation of the headpiece.

The push-to-talk foot switch, a speaker, and the control head were mounted in the hoist house at the double-drum console. The transceiver, battery charger, and battery were located in the basement of the hoist house.

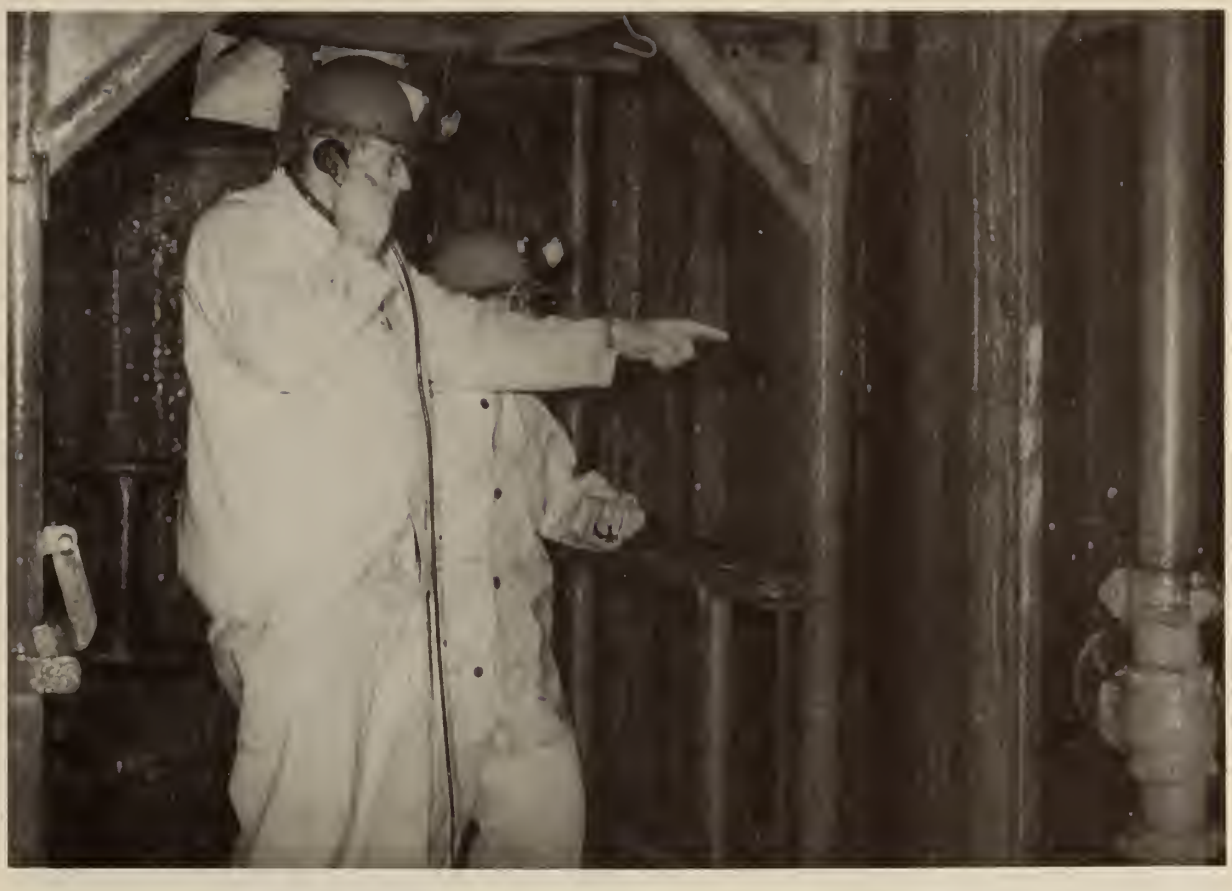

FIGURE 9. - Shaft inspection using hoist phone.

Signals from the toroidal coupler installed around the hoist rope at the headframe were conveyed back to the hoist house by a coaxial cable.

The system provided satisfactory two-way voice communication over the entire depth of the 4,500-foot shaft. However, a great deal of preventive maintenance was required to keep the system operational. The high current drain of the cage unit required charging the battery twice a week, a considerable nuisance since the battery was mounted under the cage and was rather inaccessible. The wet environment, continual pressure changes, and corrosive qualities of the shaft environment has a detrimental effect on electronic components and connectors. Servicing the equipment under the cage was nearly impossible since the cage was in continual use.

Grace Mine.--A system with equipment identical to that at the Lucky Friday mine was installed at the Grace mine of the Bethlehem Mines Corp. in September 1974 and continues to provide excellent service. The cage transceiver (including handset, speaker, and controls), control head, and battery are installed within the cage. This is possible because of the large cage (about 10 by 14 feet). The control head was recessed in the cage wall to provide clearance for material handling. The protected environment at Grace mine, along with a routine maintenance schedule, has provided successful operation

FIGURE 10. - Hoist-house installation at Grace mine.

FIGURE 11. - Cage installation at Grace mine.

for more than 2 years. The Grace mine has employed an experienced electronic technician to service its communications and environmental-monitoring equipment. The installation is shown in figures 10 and 11.

Improved Hardware

As a result of experience with hoist-communication systems at the Grace and Lucky Friday mines, an improved hoist communication system was designed and constructed. This version is self-contained in an 8-inch by 10-inch by 2-1/2-inch package.

A protective housing was also provided to enclose both the transceiver and battery, which is mounted below the transceiver. When the transceiver is mounted in small cages where space is at a premium, the unit may be recessed in the cage wall without the protective enclosure, and the battery may be installed either above or below the cage. The protective enclosure is fabricated from angle iron, which makes it durable enough to protect the transceiver from the continual abuse from loading and unloading timber, drill rods, and similar material being transported underground in a people-and-material cage.

A noise-canceling microphone, push-to-talk switch, and moisture-resistant speaker are mounted on the front panel of the unit. A provision is made for attaching a remote speaker for use in multideck cages. A common lead-acid motorcycle-type battery was chosen since it is readily available locally and from mail-order catalogs. Battery life is at least 168 hours.

All terminals on the cage unit are screw-type barrier strips for ease of installation, and threaded knockouts are provided on the protective enclosure for conduit. A remote handset input is available on the transceiver for use during shaft inspection and maintenance. A remote outlet was installed above the cage on the monkey deck for the convenience of attaching the remote handset. Input terminals for a slack-rope-alarm switch are provided on the transceiver; the alarm signals the hoistman with an intermittent beep if there is slack rope, either intentionally or unintentionally. In addition to the slack-rope signal, an on-cage belling signal is provided. A "pull-bottle" switch wired to this input is used to signal the hoistman in the same manner that a pull bottle is used in a conventional shaft station.

The hoistman's transceiver is identical to the cage equipment except that the protective enclosure is not necessary for the surface installation. A combined power supply and battery charger powers the hoistman's unit and charges the spare hoist battery, which is changed once a week.

A foot-operated, push-to-talk switch located beneath the hoist console is the only operating control necessary. The hoistman is also provided with a boom microphone, which is positioned for his/her convenience.

Sunshine Mine.--Two of these improved communication systems were installed at the Sunshine mine in Kellogg, Idaho. The first set of equipment, installed on the Jewell shaft, provides communication on the chippy hoist from

the surface to the 4,000-foot level. A second installation, on the No. 10 shaft, again on a chippy hoist, extends communication from the 3,100-foot level to the present mine depth of 6,000 feet (fig. 12).

FIGURE 12. - Cage installation at Sunshine mine.

CONCLUSION

A Bureau of Mines program has resulted in significant improvements in hoist communication. A model was developed to aid in hardware design. Experimental results proved that by employing sensitive, low-frequency receivers and properly designed toroidal couplers, a low-power portable system can be achieved. In addition, emergency communication equipment was developed for MESA, a reliable voice and signaling system was built for operational use, and installations at the Sunshine and Grace mines have demonstrated that practical and effective hoist communication can increase safety and improve productivity.

BIBLIOGRAPHY

1. Lagace, R. L., M. L. Cohen, A. G. Emslie, and R. H. Spencer. Propagation of Radio Waves in Coal Mines. Arthur D. Little, Inc., Final Report--Task F, Task Order No. 1, Bureau of Mines Contract H0346045, October 1975, 172 pp.; available for consultation at the Bureau of Mines Mining and Safety Research Center, Pittsburgh, Pa.

2. Lagace, R. L. Emergency and Operational Mine Communications. V. 1, Ch. 5, Arthur D. Little, Inc., Final Report, Bureau of Mines Contract H0122026, January 1974, 64 pp.; available for consultation at the Bureau of Mines Mining and Safety Research Center, Pittsburgh, Pa.

3. Wait, J. R., and D. A. Hill. Theory of the Transmission of Electromagnetic Waves Down a Mine Hoist. Radio Sci., v. 10, No. 6, June 1975, pp. 625-632.

COMMUNICATIONS FOR HAULAGE LOOP-AROUNDS

by

Robert A. Bradburn[1]

SUMMARY

Reliable communication is needed between locomotive operators and workers who uncouple cars in mines that use loading-track loops. The Bureau of Mines proposes two systems that could accomplish this communication link using commercially available hardware. One system uses telephones and trolley phones; the other, a walkie-talkie radio system. One mine developed a system similar to the proposed telephone and trolley-phone system and has already reported success. Also, a private company has developed a medium-frequency, wireless radio transceiver that reportedly has the required range for the communication necessary between these two workers.

BACKGROUND

Many coal mines use loading track loops for loading mined coal at the sections before transporting it to the surface. This type of operation involves the coordinated activities of two individuals: a "snapper," who couples and uncouples the coal cars; and a locomotive operator, or "motorman," who moves the train backward and forward at prescribed times. If the snapper is not in the clear when the train is moved, its sudden motion can injure or kill him or her. Thus, effective communication between the motorman and snapper is vital (fig. 1).

Because of the curvature of the loop track and the location of the locomotive on the main haulage track, the two individuals are not within sight or hearing of each other. Without communication, or at least some system of signaling, coordination is difficult unless other workers are stationed alongside the track to relay information. However, this wastes labor. It is clear that the safety and efficiency of the loading operation could be vastly improved if there were a reliable communication link between the motorman and snapper.

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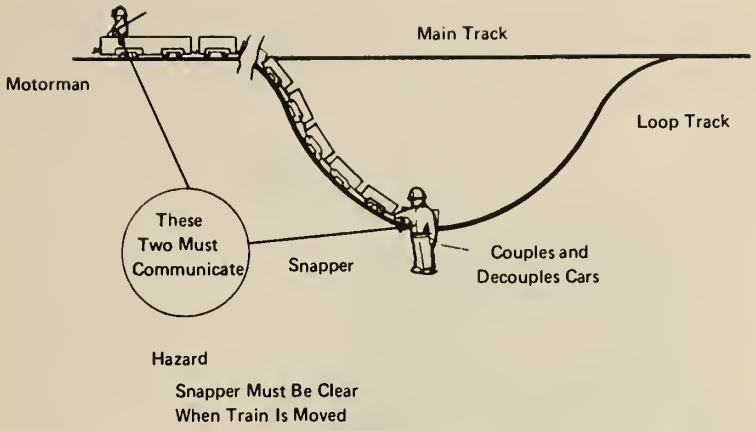

FIGURE 1. - Diagram showing need for communication in haulage loop-around.

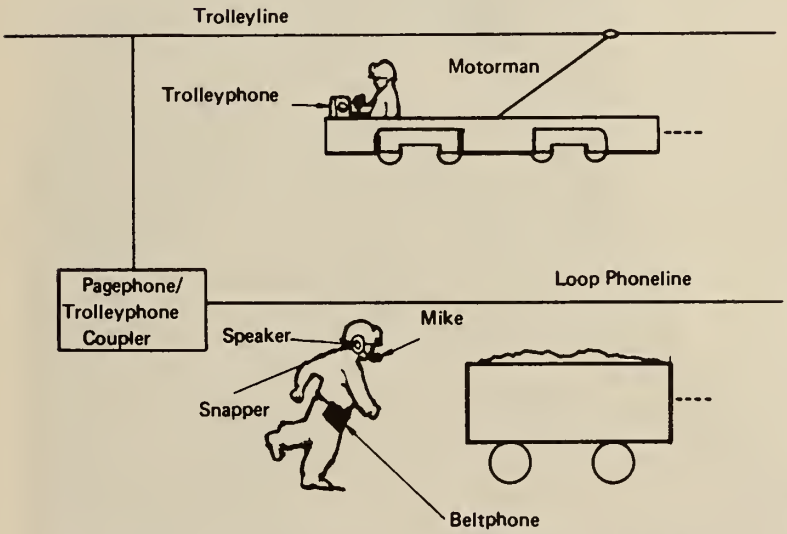

FIGURE 2. - Telephone and trolley phone system.

DISCUSSION OF SYSTEMS

The design of any practical system must adhere to certain constraints. For this system, requirements are that it does not interfere with other communications, is convenient, has a restricted range so that similar systems can be used elsewhere in the mine, and can be built with commercially available hardware.

The system must have a range of 1,500 feet, maximum reliability, and full loop-around coverage.

Typically, a range of 1,500 feet is necessary to assure adequate coverage for the maximum separation between the snapper and motorman. The equipment must be reliable and convenient, and coverage throughout the total length of the loading track is required.

The Bureau of Mines is recommending two systems that can presently be implemented using commercially available hardware: the telephone and trolley-phone system and the walkie-talkie radio system. A third system may soon become available.

Telephone and Trolley-Phone System

In the telephone and trolley-phone system (fig. 2), the snapper communicates by means of a belt-carried, miniature mine telephone known as a "belt phone." A phone line is installed on the rib or roof of the mine along one side of the loading track. The belt phone can be connected to this line by an extension cord that has insulation-piercing clips at one end. Alternatively, receptacles that allow the belt phone to be plugged in at convenient points can be provided on the line.

FIGURE 3. - Miner wearing belt phone.

A coupler connects the phone line and the trolley line. Phone line signals are converted to trolley-line signals and vice versa by this coupler. The motorman communicates by a trolley phone, which operates on a frequency different from that of the haulage communications.

If duplicate systems are used in a mine, the range of the trolley-line signals has to be restricted by appropriately attenuating the transmitter output. This system can be implemented using standard trolley phones and phone-line-to-trolley-line couplers. In addition, a belt phone developed by the Bureau of Mines (fig. 3) is now commercially available from SETCOM, Mountain View, Calif. Equipped with a hardhat-mounted speaker and an adjustable-boom-type microphone, it has outgoing paging capability and will operate compatibly with available phone-line-to-trolley-line couplers.

Walkie-Talkie System

The walkie-talkie radio system uses very-high-frequency (VHF) or ultrahigh-frequency (UHF) portable radio equipment. Both the motorman and snapper are equipped with walkie-talkies (fig. 4).

Because of the curvature of the loop tunnel, propagation of radio waves is severely restricted. In fact, direct radio communication between the two individuals is not possible using conventional equipment. However, this deficiency can be overcome with a dual-frequency radio repeater connected to a coaxial cable. The cable carries the radio signals, and the repeater effectively boosts them to a higher power level.

The coaxial cable extends along the loading track and down the main haulageway far enough to assure communication coverage to the motorman. Cables several hundred feet shorter can be used if an appropriate antenna is connected at the end. Commercially available portable radio transceivers and repeaters can be used to implement this system. Discretion should be used in selecting a coaxial cable, but an inexpensive RG-8 type should work in most cases.

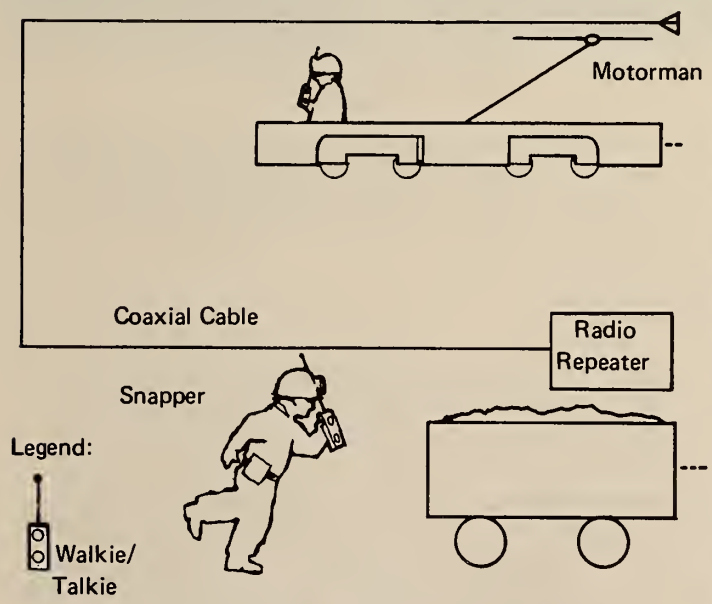

FIGURE 4. - Walkie-talkie radio system.

Medium-Frequency Radio System

Lee Engineering Co. has developed a medium-frequency (MF) radio transceiver (425 kHz) with sufficient range, without the aid of a cable, for snapper-motorman communications (fig. 5).

FIGURE 5. - Miner wearing portable MF radio equipment.

Transmission is aided by the conductors normally present in the loop-around. Without such conductors, a suitable range is only obtained when the electrical properties of the coal and overburden are favorable. The transceivers are expected to be marketed in the near future.

EXPERIENCE

The Ireland mine (Consolidation Coal Co.) has successfully used an interface system between the phone and trolley lines to provide motorman-snapper communication at its Roseby portal. The system is diagramed in figure 6. A remote interface, fabricated by technicians at the mine, acts as a coupler between the trolley line and a dedicated phone line. The motorman can communicate via the existing trolley-phone system, whereas the snapper must communicate via the phone line using a modified telephone handset. A twisted-pair phone line, with jackboxes connected at 50-foot intervals, is strung up in the loop-track area and connects to the dedicated phone line. The snapper plugs his handset into a nearby jackbox to establish communication to the motorman.

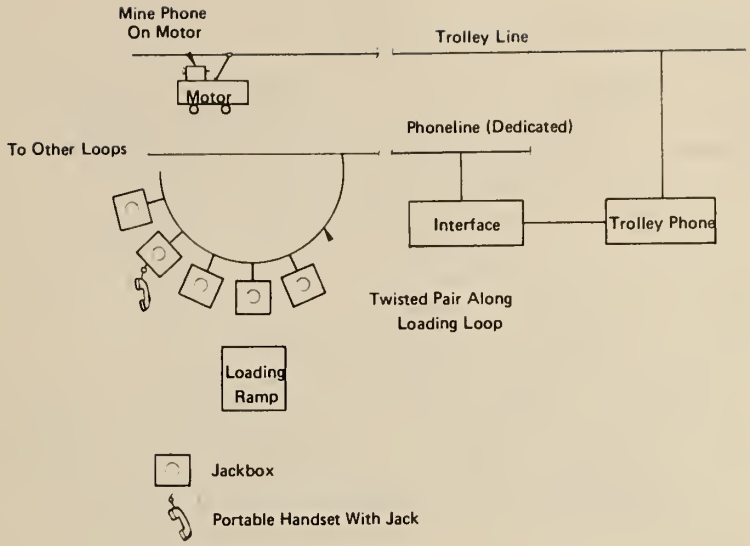

FIGURE 6. - Diagram showing snapper-motorman communication at Roseby portal (Ireland mine).

FUTURE OUTLOOK

Effective communication between the snapper and motorman can provide the coordination needed to eliminate uncertainties regarding train movement in the mine. This should result in improved efficiency and a reduction in the number of accidents related to the loading operation. Systems can be custom made from available telephone and trolley-phone equipment. Guided wireless VHF and UHF equipment is similarly available for custom systems. It is expected that MF wireless equipment will shortly be commercially available.

BIBLIOGRAPHY

1. Lagace, R. L., M. L. Cohen, A. G. Emslie, and R. H. Spencer. Propagation of Radio Waves in Coal Mines. Arthur D. Little, Inc., Final Report--Task F, Task Order No. 1, Bureau of Mines Contract H0346045, October 1975, 172 pp.; available for consultation at the Bureau of Mines Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.

2. Mountain, N. L., and J. V. Nickel. Recent Developments in Communications and Fan Monitoring for Underground Mines. Paper in Proceedings: The Third WVU Conference on Coal Mine Electrotechnology, ed. by M. D. Aldridge. BuMines Open File Rept. 16-77, 1976 pp. 16:1-16:14; available for reference at Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Bruceton and Pittsburgh, Pa., Spokane, Wash.; at the Energy Research and Development Administration library in Morgantown, W. Va.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 263 247/AS.

TRACKLESS-TROLLEYLESS MEDIUM-FREQUENCY RADIO

by

Robert L. Chufo[1]

SUMMARY

Vehicular communication is essential to safe, efficient coal mining. Vehicles powered by a trolley system can use the trolley wire to carry signals between vehicles and to and from the dispatcher. However, the number of mines using vehicles that are not trolley-powered is increasing. Thus, there is need for a communication system that will operate independently of a trolley wire. The Bureau of Mines is evaluating the communication needs in nontrolley mines and will propose a set of equipment specifications and operating recommendations.

BACKGROUND

Communications with underground mining vehicles are normally made using low-frequency (LF) frequency-modulated (FM) carrier equipment coupled to the trolley wire of electric vehicles operating on an extensive track system. However, an increasing number of both newly developed and older mines have been abandoning tracked trolley vehicles and are conducting their haulage, maintenance, and personnel transport operations with trackless, rubber-tired vehicles. This change to trolleyless vehicles requires a search for alternative forms of underground communication. The Bureau has developed portable LF equipment that can be used by roving personnel in coal mines. Information gathered from the operation of this equipment will be used in the search for ways of extending communication to trackless vehicles.

DISCUSSION OF POTENTIAL SYSTEM

Several methods exist for providing communication between underground mining vehicles. The Bureau has studied high-frequency (HF) systems utilizing the so-called "leaky-feeder" cable to carry signals throughout a mine. Work in the medium-frequency (MF) area has shown that signals follow the existing mine wiring for great distances. The Bureau is now further developing the MF concept to the stage where a practical roving-miner-to-roving-miner system can be demonstrated in a working mine. The program now in progress on a trackless-trolleyless communication system will (1) determine the communication requirements of vehicles in the mine, (2) develop equipment that will meet these requirements, (3) demonstrate the equipment in an operating mine, and (4) result in publication of a set of recommendations for equipment construction and operation that will be made available to equipment manufacturers and mine operators.

[1]Electrical engineer, Pittsburgh Mining and Safety Research Center, Bureau of Mines, Pittsburgh, Pa.

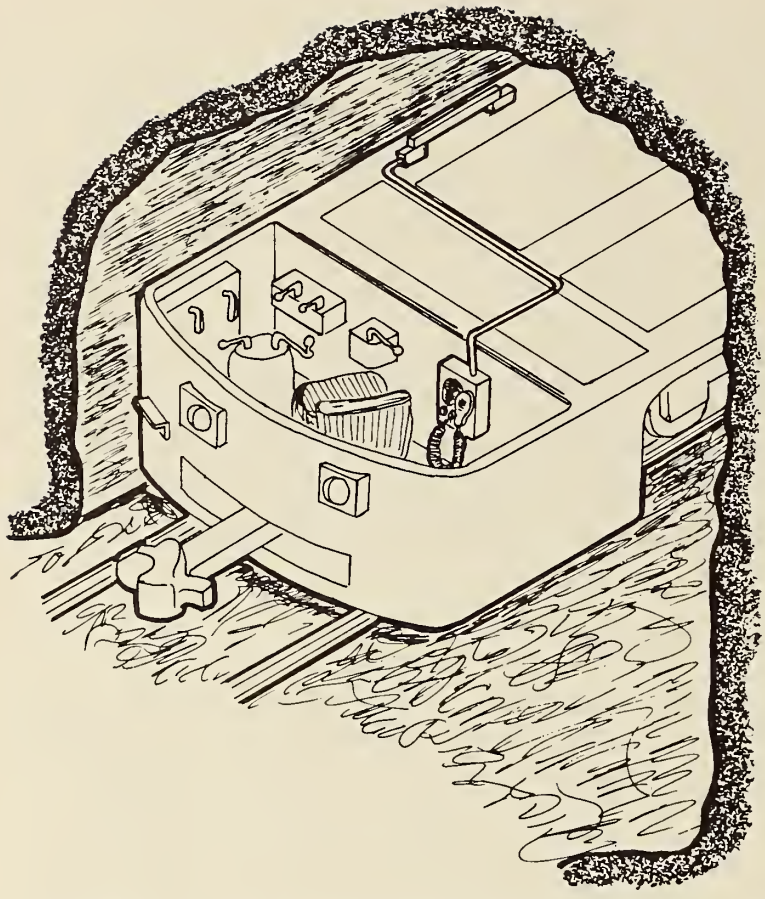

FIGURE 1. - Artist's concept showing proposed equipment—transceiver, microphone, speaker, and antenna—mounted on the vehicle.

Figure 1 is an artist's conception of possible equipment mounted on a mining vehicle. The equipment includes a radio mounted on every vehicle, together with an antenna that will permit communication between the vehicles in a mine and between the vehicles and the vehicle dispatcher. Equipment must have backup battery power so that communication is maintained during power failure, and the equipment must be durable, easily serviceable, and capable of extended service with minimum maintenance. The program now underway consists of a study of mines, mine vehicles, and methods for effective vehicular communications. Actual in-mine tests of the recommended system will be conducted. A detailed system will be recommended based on the results of the program. Once the system has been developed, the program will demonstrate the system under actual operating conditions. The results of the in-mine operational tests will be used to improve the system and equipment specifications if necessary.

When this program has been completed, a proven design will be available with equipment specifications, both electrical and mechanical, that can be used as the basis for manufacturing practical hardware for a wireless communication system. Methods will also be suggested to connect the mine telephone system with the vehicular system to provide two-way voice coverage on the mine telephone system.

PROGRESS TO DATE

Through various Bureau of Mines programs, the factors that affect radio transmission in the mine environment are being determined. In the frequency band between 200 and 900 kHz, for instance, there are some mines with characteristics that increase the coverage area. We are learning what factors influence the operating range of low-powered transceivers. In addition, we are learning how to account for the coupling of signals to mine conductors, which tends to increase radio coverage distance, and are devising simple ways to predict the operating ranges in different seams and mines.

BIBLIOGRAPHY

1. Anderson, D. T., and L. R. Wilson. Mine Wireless Communication System for Coal Mines. Paper in Proceedings: The Third WVU Conference on Coal Mine Electrotechnology, ed. by M. D. Aldridge. BuMines Open File Rept. 16-77, 1976, pp. 18:1-18:10; available for reference at Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Bruceton and Pittsburgh, Pa., Spokane, Wash.; at the Energy Research and Development Administration library in Morgantown, W. Va.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 263 247/AS.

2. Emslie, A. G., and R. L. Lagace. Propagation of Low and Medium Frequency Radio Waves in a Coal Seam. Radio Sci., v. 11, No. 4, April 1976, pp. 253-261.

3. Wait, J. R. Note on the Theory of Transmission of Electromagnetic Waves in a Coal Seam. Radio Sci., v. 11, No. 4, April 1976, pp. 263-265.

APPENDIX.--COMMUNICATION REPORTS

The following is a list of reports available in the area of communications. These reports may be obtained from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Va. 22161. Microfiche copies are $2.25 each, and paper copies are available at the prices indicated.

Company name	NTIS No.	NTIS price	Title
Westinghouse			Coal Mine Rescue and Survival
	PB 208 266	$5.50	V. 1--Survival Subsystem
	PB 208 267	9.00	V. 2--Communications/Location Subsystem
	PB 208 268	9.00	V. 3--Rescue Subsystem
J. H. Crary	PB 213 204	9.00	Determination of the Electromagnetic Environment
A. D. Little	PB 218 688	4.00	A Field Program and Instrumentation System for EM Noise Measurements
A. D. Little	PB 218 658	4.50	Assessment of EM Noise Measurements Taken by Bureau of Mines Contractors
Westinghouse Georesearch	PB 226 600/AS	5.50	EM Location System Prototype and Communication Station Modification
West Virginia University	PB 225 862/AS	6.00	Analysis of Communication Systems
National Bureau of Standards	PB 226 773/AS	4.00	Survey Report of the USBM EM Noise Measurement Program
National Bureau of Standards	PB 226 781/AS	3.50	Applicability of Speech Bandwidth Compression Techniques in Mine EM Communications
Colorado School of Mines	PB 231 154/AS	7.75	Thru-the-Earth Electromagnetics Workshop
Mine Safety Appliances			Develop, Assemble, and Install a Permissible Surveillance and Communication System in the Bureau of Mines Mining and Safety Research Center Coal Mine, at Bruceton, Pa.
	PB 231 574	4.00	V. 1--System Description
	PB 231 575	4.50	V. 2--Circuit and Installation

Company name	NTIS No.	NTIS price	Title
Westinghouse Georesearch	PB 232 880/AS	$4.50	Electromagnetic Location Experiments in a Deep Hardrock Mine
Continental Oil Co.	PB 232 887/AS	5.50	Seismic Miner Detection and Location System; Phase I--Final Report
A. D. Little			Survey of EM and Seismic Noise Related to Mine Rescue Communications
	PB 235 069/AS	6.00	V. 1--Emergency and Operational Mine Communications
	PB 235 070/AS	10.50	V. 2--Seismic Detection and Location of Isolated Miners
Westinghouse	PB 235 604 (set)	21.50	Trapped Miner Location and Communication System Development Program
	PB 235 605/AS	7.50	V. 1--Development and Testing of an EM Location System
	PB 235 606/AS	4.50	V. 2--Detection and Location of Entrapped Miners by Seismic Means (by Dr. S. J. Duda)
	PB 235 607/AS	5.00	V. 3--Monitoring, Locating, and Communication System for Normal Mine Operation and Post-Disaster Rescue Operations
	PB 235 608/AS	4.50	V. 4--Performance Test and Evaluation of a Full Wave Location Transmitter
Collins Radio	PB 237 218/AS	4.00	System Study of Coal Mine Communications
Colorado School of Mines	PB 237 852/AS	5.50	Research on the Transmission of EM Signals Between Mine Workings and the Surface
A. D. Little	PB 240 552/AS	4.50	Investigation of Communication Standards as Related to Coal Mines
Collins Radio	PB 240 481/AS	3.50	Waveform Generator for EM Location of Trapped Miners
National Bureau of Standards	COM 741 1688/AS	4.00	Surface Magnetic Field Noise Measurements of Geneva Mine
National Bureau of Standards	COM 741 1687/AS	6.00	Electromagnetic Noise in Grace Mine

Company name	NTIS No.	NTIS price	Title
National Bureau of Standards	COM 741 1717/AS	$6.75	Electromagnetic Noise in McElroy Mine
National Bureau of Standards	COM 741 1718/AS	5.50	Electromagnetic Noise in Itmann Mine
National Bureau of Standards	COM 741 1450/AS	4.50	Time and Amplitude Statistics for Electromagnetic Noise in Mines
National Bureau of Standards	COM 751 0258	6.00	Electromagnetic Noise in Lucky Friday Mine
Continental Oil Co.	PB 243 068/AS	5.00	Seismic Mine Monitor System--Phase IV report
Continental Oil Co.	PB 241 504/AS	4.00	Seismic Mine Monitor System--Phase II report
A. D. Little			Technical Services for Mine Communications Research
	PB 249 829/AS	5.00	Task D--Applicability of Available Frequency Multiplexed Carrier Equipment
	PB 249 830/AS	5.00	Task B--Applicability of State-of-the-Art Repeaters for Wireless Mine Communications
	PB 249 831/AS	5.00	Task A--Applicability of State-of-the-Art Voice Bandwidth Compression Techniques for Wireless Mine Communications
Collins Radio	PB 244 896/AS (set)	20.00	Research and Development Contract for Coal Mine Communication Systems
	PB 244 897/AS	4.50	V. 1--Summary and Results of System Study
	PB 244 898/AS	5.50	V. 2--Mine Visits
	PB 244 899/AS	7.50	V. 3--Theoretical Data Base
	PB 244 900/AS	4.50	V. 4--Environmental Measurements
Continental Oil Co.	PB 251 705/AS	4.00	Seismic Mine Monitor System

The following publications are available without charge from the Publications Department, U.S. Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213:

Lamonica, J. A., R. L. Mundell, and T. L. Muldoon. Noise in Underground Coal Mines. BuMines RI 7550, 1971, 11 pp.

Lee, F. R. Permissible Mine Equipment Approved by the Bureau of Mines During 1967-68. A Supplement to Bulletin 543 and Information Circulars 8220, 8299, and 8372. BuMines IC 8463, 1970, 25 pp.

Lepper, C. M., and J. H. Scott. An Improved Electrical Resistivity Field System for Shallow Earth Measurements. BuMines RI 7942, 1974, 20 pp.

Parkinson, H. E. Mine Pager to Public Telephone Interconnect System. BuMines RI 7976, 1974, 14 pp.

U.S. Bureau of Mines (Staff--Mining Research). Mine Communications. Proceedings: Bureau of Mines Technology Transfer Seminar, Bruceton, Pa., Mar. 21-22, 1973. BuMines IC 8635, 1974, 86 pp.

In addition, Preprint No. 76-F-133, entitled "A Review of Research on Underground Mining Communications," by John N. Murphy and Howard E. Parkinson is available from the Society of Mining Engineers of AIME, 540 Arapeen Drive, Salt Lake City, Utah 84108.

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